



Early Action Work Plan and Operations and Maintenance Plan

Version 1.1

20th Street & Factor Avenue

Water Quality Assurance
Revolving Fund (WQARF) Site
Yuma, Arizona

September 6, 2016
Contract Number ADEQ14-077538

CALIBRE

Matrix
DESIGN GROUP 

**EARLY RESPONSE ACTION WORK PLAN and
OPERATIONS and MAINTENANCE PLAN**

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Water Quality Assurance Revolving Fund (WQARF) Registry Site

Yuma, Arizona

**Water Quality Assurance Revolving Fund
Arizona Superfund Response Action Contract**

Contract Number: ADEQ14-077538

Prepared for:



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ACRONYM LIST

ADEQ	Arizona Department of Environmental Quality
AWQS	Aquifer Water Quality Standard
bgs	below ground surface
BOD	biological oxygen demand
Cl ⁻	chlorine ion
COCs	chemicals of concern
COD	chemical oxygen demand
CSM	Conceptual Site Model
cis-1,2-DCE	cis-1,2-dichloroethene
EDD	Electronic Data Deliverable
EPA	U.S. Environmental Protection Agency
ERA	Early Response Action
ERD	Enhanced reductive dechlorination
FS	Feasibility Study
ft	feet
HASP	Health and Safety Plan
H ⁺	hydrogen ion
IDW	Investigation-Derived Waste
MNA	Monitored natural attenuation
mV	millivolts
MS/MSD	Matrix Spike/Matrix Spike Duplicate
O&M	Operation and maintenance
ORP	Oxidation Reduction Potential
PCE	Tetrachloroethene
PDB	Passive Diffusion Bag
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RI	Remedial Investigation
Site	20 th Street and Factor Avenue WQARF Site
SOP	Standard Operating Procedure
TOC	Total organic carbon
TCE	Trichloroethene
UIC	Underground Injection Control
USGS	United States Geological Survey
µg/L	micrograms per liter

VC	vinyl chloride
VOC	volatile organic compound
WQARF	Water Quality Assurance Revolving Fund

1.0 INTRODUCTION

This Work Plan/O&M Plan (Plan) has been prepared to describe the planned approach for implementing an Early Response Action (ERA) for groundwater treatment in a portion of the plume at the 20th Street and Factor Avenue Water Quality Assurance Revolving Fund (WQARF) Registry Site (the Site). The Plan has been prepared for the Arizona Department of Environmental Quality (ADEQ). The Matrix-CALIBRE team is performing this work under contract number ADEQ14-077538.

The source of contamination at the Site is associated with waste disposal activities at a former photo processing facility (the Facility). Chemicals used at the Facility include tetrachloroethene (PCE) and cyanide. PCE breaks down in the environment to trichloroethene (TCE) and 1,1-dichloroethene, which are also chemicals of concern (COCs) at the Site. Environmental investigations have been undertaken at the Site over a period of 25 years to characterize the nature and extent of contamination in soil, soil vapor, and groundwater. A Remedial Investigation (RI) report presented this information and characterized the risk to human health and the environment (Tetra Tech, 2014). The media of primary concern is groundwater, where COCs have migrated up to 4,500 feet (ft) from the Facility to the west-northwest. A prior ERA was completed at the Facility in 2002, in which shallow soil containing elevated levels of cyanide was removed from the Site and a cap was placed over the excavation area. Liquids and sludge containing PCE were also removed from septic systems at the Facility.

The Feasibility Study (FS) identified a reference remedy for the Site that includes enhanced reductive dechlorination (ERD) for groundwater, monitored natural attenuation (MNA), and inspection and maintenance of the asphalt cap at the Facility (Matrix-CALIBRE, 2016a). ADEQ has not yet selected a final remedy for the Site. This Plan describes a proposed approach to implement ERD in the portion of the groundwater plume with the highest concentrations as an ERA to reduce concentrations and begin efforts to protect down-gradient wells. This Plan also presents associated monitoring recommendations to document the effectiveness of the ERD measures.

The field work required to implement the Plan includes installation of six aquifer remediation wells that will be used to inject reagents to enhance reductive dechlorination of contaminants at locations with the highest concentrations of PCE and TCE. Once the wells are installed, reagents will be added to the wells and monitoring will be conducted to evaluate the effectiveness of the ERD treatment.

1.1 Site Description and Background

The Site is in an area of Yuma that includes a mixture of commercial and light industrial businesses, warehouses, residential neighborhoods, encompassing an area of approximately 80 acres. The Site is roughly bounded by 17th Street to the north, 21st Street to the south, 4th Avenue to the west, and Kennedy Lane to the east (Figure 1-2). Releases of volatile organic compounds (VOCs) and cyanide are documented at the former Houston Photo Products Facility (Facility) (Tetra Tech, 2014). To date, no other sources of VOCs and cyanide have been identified in the area. The Facility is located near the southeast corner of the 20th Street and Factor Avenue intersection. Based on 2016 groundwater monitoring data, the contaminant plume extends approximately 4,500 ft to the northwest down-gradient from the Facility.

Floating petroleum hydrocarbon free product has been observed intermittently in several wells on the north side of 20th Street (Figure 1-2), which is probably related to a diesel release from a Union Pacific Yuma Yard facility, also known as the Dieselveille site; a separate site located to the east of the Facility.

1.2 Early Response Action Rationale

The Arizona Administrative Code, section R18-16-405 addresses ERAs. Section R18-16-405A summarizes the goals of an ERA as:

1. Address current risk to public health, welfare, and the environment;
2. Protect or provide a supply of water;
3. Address sources of contamination; or
4. Control or contain contamination where such actions are expected to reduce the scope or cost of the remedy needed at the site.

The ERA proposed in this Plan will meet ADEQ's ERA Goals through the following objectives:

Objective 1 - The ERA will address current risk to public health, welfare, and the environment by implementing actions to reduce chemical concentrations in groundwater hotspots that are substantially higher than the Aquifer Water Quality Standard (AWQS).

Objective 2 - The ERA will protect or provide a supply of water by reducing the likelihood that school irrigation wells located downgradient of the Site will be impacted in the future.

Objective 3 - The ERA will not address sources of contamination because releases from the source area stopped many years ago and existing data suggest there is no longer an active source.

Objective 4 - The ERA will control or contain contamination where such actions are expected to reduce the scope or cost of the remedy needed at the Site by taking immediate steps to minimize the expansion of the plume, which if left unchecked would require a more extensive and expensive remedy.

Information available in the RI Report and FS Report indicates that ERA objectives 1, 2, and 4 are applicable at the Site. Additionally, R18-16-405I indicates that if a water supply is located within 1 mile down-gradient of the aerial extent of contamination, an ERA should be considered. One of the rationales for the ERA is the proximity (within 1 mile) of two schools, which use groundwater for irrigation.

In accordance with Section R18-16-405B, while ADEQ has not yet selected a remedy for the Site, the FS report provides sufficient detail regarding site characterization, remedial technologies, costs, and potential risks to public health or welfare or the environment to select appropriate technologies for an ERA. In this context, elements of the Reference Remedy as described in the FS report, have been selected for the ERA. This Plan was prepared to satisfy the requirements of R18-16-405C and D.

Section R18-16-411E of the A.A.C. requires "ADEQ to approve an operation and maintenance plan for any WQARF site where an early response action involves treatment of water to remove contaminants of concern at a site". Elements of the operations and maintenance (O&M) plan, as they relate to the ERA described herein are provided in Section 4.0.

1.3 Organization of this Work Plan/Operation and Maintenance Plan

The following sections provide information on the project background and describe the planned activities to meet the project objectives. Section 2.0 provides a summary of the conceptual site model (CSM). Section 3.0 provides background on ERD and describes the general approach planned for the Site. Section 4.0 describes operation and maintenance (O&M), ERD implementation and remedial optimization measures planned, and performance monitoring. Section 5.0 summarizes performance monitoring procedures and related quality control procedures. Section 6.0 summarizes general Health and Safety procedures, Section 7.0 presents project team roles and responsibilities, and Section 8.0 lists references cited in this Plan.

Standard Operating Procedures (SOPs) and the Health and Safety Plan (HASP) are presented in Attachments A and B, respectively. The work to be completed under this Plan will be conducted in accordance with the programmatic Quality Assurance Project Plan (QAPP) (Matrix-CALIBRE 2014a). Attachment C includes the required Permits (to be added when received); Section 3.2 discusses the anticipated permits required and these will be included as they are issued along with any other details on permit conditions that need to be described and implemented. Attachment D includes local utility maps, details and utility clearance information.

2.0 CONCEPTUAL SITE MODEL

The objective of a CSM is to assemble and summarize existing data in a consistent framework so that project stakeholders can understand the Site conditions and make informed decisions. An updated CSM was developed for the Site and presented in considerable detail in the FS report (Matrix-CALIBRE 2016a). The updated CSM is intended to be used by ADEQ to assist in making remedial action decisions; it summarizes key Site conditions that are relevant to the anticipated project decisions going forward and is used to identify data gaps, if any, that can be further evaluated in a data quality objectives process.

The CSM forms the basis for organizing Site data, helps focus proposed data collection efforts, and ultimately, tests the performance of proposed and implemented remedies. As such, the CSM needs to reflect the best interpretation of all relevant Site data at any given time. As new data are collected, they should be tested for consistency with the CSM and the CSM will be modified as appropriate.

As it relates to this ERA and remedial optimization efforts, the CSM indicates that PCE and related degradation compounds are present in groundwater. These contaminants are migrating to the west-northwest forming a plume. As such, it is anticipated that the duration of remedial efforts can be shortened by treating groundwater at the hot spot near MW-18B and MW-21B. This can be confirmed by implementing ERD and conducting performance monitoring, in addition to the periodic Site-wide monitoring.

2.1 Geology and Hydrogeology

The Site lies on the Yuma Mesa at approximately 200 ft above sea level, which is approximately 100 ft higher than the Yuma Valley (Dickinson, et al., 2006). From oldest to youngest, the sediments underlying the Site are the wedge zone, coarse-gravel zone, and the upper fine-grained zone (Olmsted, et al., 1973). Clay A and Clay B, which are within the upper fine-grained zone may be present in localized areas beneath the Site (Dickinson, et al. 2006). The wedge zone is composed of fluvial and deltaic deposits of sand, silt, clay, and gravel from the Colorado and Gila Rivers.

The coarse-gravel zone is a complex of gravel bodies of different ages deposited by the Colorado and Gila Rivers (Olmsted, et al. 1973). The zone ranges in thickness from 0 to possibly more than 150 ft; the top lies at an average depth of 100 ft beneath the valleys and 170-180 ft beneath the Yuma Mesa. The earliest identification of the coarse-gravel zone described it as a widespread, blanket-like deposit underlying most of the Upper Mesa, the intervening Yuma Mesa and river valleys. Later more detailed studies by the U.S. Bureau of Reclamation and the United States Geological Survey (USGS) demonstrated that the coarse-gravel zone is a complex series of multiple gravel bodies of different ages. As a consequence, the top and bottom of the coarse-gravel zone are at different elevations from place to place.

Some well logs used by the USGS to identify the coarse-gravel zone include descriptions such as “coarse gravel, clean gravel, sandy gravel, or pea gravel”, but also generally include multiple inter-bedded sequences of sands/silts and clays within the unit. Other well logs include descriptions such as “Sand and gravel, gravelly sand; Sand and scattered gravel; Sandstone cemented sand; and sand”, and also include multiple inter-bedded sequences of silts and clays within the unit.

Most of the monitoring wells drilled during the RI were terminated within the upper, fine-grained zone (sand and silt). Two distinct fine-grained beds are identified in the upper portions of the upper fine-grained zone (Olmsted, et al. 1973). These fine-grained beds are identified in many wells beneath portions of eastern Yuma Valley and western Yuma Mesa. The lower fine-grained bed, informally designated as the “Clay A” is a marker that is described as “not far above the coarse-gravel zone beneath Yuma Valley and adjacent parts of Yuma Mesa”. The upper fine-grained unit is designated as “Clay B”. The Clay A unit is found at about 175 ft below ground surface (bgs), and the Clay B unit at about 100 ft bgs, in many well logs and the cross sections for the Site (Tetra Tech 2014).

Groundwater level maps presented in the RI report indicate that groundwater flows to the west northwest. The hydraulic gradient is approximately 0.001 ft/ft. Groundwater is encountered between 70 to 75 ft bgs at the Facility and at 80 to 85 ft bgs in wells at the west end of the Site. The RI Report assigned wells screened above Clay B, to a depth of 105 ft, to “Zone A”. Wells screened below this, to a depth of 170 ft, above Clay A, were assigned to “Zone B”. Wells screened below 170 ft were assigned to “Zone C”. Although monitoring wells have been classified into Zone A, Zone B, and Zone C based on the depth of the screen intervals, the depth to groundwater in each zone is similar, suggesting that the Clay A and Clay B units, where present, do not act as aquitards over the scale of the Site.

A range of estimates for groundwater and contaminant transport velocities have been developed for the Site. A velocity of 100 ft/yr for Zone B was estimated based on a groundwater model (GeoTrans, Inc. 2008). An empirical contaminant transport velocity of 280 ft/yr was estimated in a technical memorandum based on the travel time for peak concentrations between wells on the centerline of the plume (Matrix-CALIBRE, 2015).

2.2 Contaminant Distribution

Contaminated groundwater associated with releases from the Facility has primarily impacted Zone A and Zone B of the aquifer. VOCs, including PCE and degradation products (mainly TCE), and cyanide are the primary COCs. The contaminant distribution is described in more detail in the RI (Tetra Tech 2014), the FS report, and in the 2016 groundwater monitoring report (Matrix-CALIBRE 2016a and b). The focus of this ERA is on PCE and degradation products present in Zone B. Groundwater contamination in that interval is described below.

Figure 2-1 shows the PCE plume in Zone B based on samples collected in February 2016. The highest PCE concentration detected in Zone B was in well MW-18B at a concentration of 1,400 micrograms per liter ($\mu\text{g/L}$). PCE in MW-18B had been near or less than the AWQS until January 2012 when it was detected at a concentration of 560 $\mu\text{g/L}$, and the PCE concentration has been consistently increasing with only a single exception in 2013. This pattern suggests transport of a slug of PCE towards and past MW-18B. PCE has not reached MW-21B, which is located approximately 800 ft to the west-northwest of MW-18B. There are a limited number of Zone B wells near the source area, but in MW-102B1 the PCE concentrations have been less than 100 $\mu\text{g/L}$ for over a decade. The PCE plume in Zone B is approximately 2,800 ft long.

Figure 2-2 shows the TCE distribution in Zone B based on samples collected in February 2016. TCE is only present in a few wells at concentrations above the AWQS. The TCE observed is believed to be derived from

the dechlorination of the parent product PCE. MW-21B is the well of most concern because the TCE concentrations have been rising significantly over the last several years.

It should be noted that near the northwest edge of the plume, there is uncertainty in the width and leading edge of the plume because of the relatively wide spacing of the wells in those areas. For example, the north-south extent of PCE contamination in Zone B at MW-18B as illustrated by the 5 µg/L contour is approximately 500 ft wide, but it could be somewhat narrower, or wider. The uncertainty in plume width and the depth of contamination at the areas targeted for treatment has an impact on the implementation of the ERA in the context of where to place the new wells and which depth intervals are selected for the well screens. The ERA implementation includes the installation of several new wells and VOC data will be collected from those wells (prior to their use for ERD treatment) to help bound the uncertainty in these areas.

3.0 ENHANCED REDUCTIVE DECHLORINATION

This section describes the activities that will be conducted at the Site to optimize remedial actions using ERD. Section 3.1 provides background on ERD; Section 3.2 lists permits that are required for the project; Section 3.3 describes the well installation plans; and Section 3.4 describes the implementation steps to start ERD treatment at the Site.

3.1 Description of ERD

Anaerobic reductive dechlorination is a naturally occurring biodegradation process whereby microbes can degrade chlorinated VOCs in groundwater. The microbes use a primary substrate as a carbon and an energy source to produce enzymes and other compounds that degrade other organic compounds. The process name of reductive dechlorination comes from the method by which these reactions strip chlorine atoms from VOC molecules present in the groundwater. To facilitate their respiration while they metabolize available carbon-energy source material, microbes must utilize electron acceptors. As electron acceptors are depleted, the groundwater environment becomes increasingly reducing (lower oxidation reduction potential [ORP]) and the microbes are forced to use successively alternative electron acceptors, ultimately using the chlorinated compounds as the electron acceptor.

3.1.1 Reductive Dechlorination

Anaerobic reduction of chlorinated compounds is a biotic process that results in substitution of a hydrogen ion (H^+) for chlorine ion (Cl^-) in the chlorinated solvent molecule as shown on Figure 3.1.

Chlorinated solvents undergo a series of reductions through dechlorination reactions; i.e., PCE to TCE to cis-1,2 dichloroethene (cis-1,2-DCE), to vinyl chloride (VC) to ethene. Each step requires a lower ORP than the previous one. PCE and TCE dechlorination occurs in a wide range of reducing conditions, whereas VC may be reduced to ethene only under sulfate reducing and methanogenic conditions (see Figure 3-1). Another potentially limiting condition is the presence of specific bacteria; some of the common bacteria include *Dehalospirillum multivorans*, *Dehalobacter restrictus* and *Dehalococcoides ethenogenes* and similar/related organisms. Some of the most recent studies/hypotheses indicate that *Dehalococcoides* (or very similar organisms) may be the primary microbes capable of utilizing the lesser-chlorinated compounds (cis-1,2-DCE and VC) for chloro-respiration.

Reductive dechlorination in particular takes place only when all other redox reactions have been depleted. The amount of energy available to microbial populations through chloro-respiration is minimal (relative to other reduction processes). This is generally thought to be the reason why all other competing processes need to be depleted prior to onset of the de-chlorinating process.

In the reduction process, the parent compound releases one chloride ion and gains one hydrogen with two electrons transferred during the process (providing an energy source for the microorganism). The source for the hydrogen and electrons in the reaction must be derived from some organic substrate in the soil/water. The hydrogen is typically released during fermentation of an organic substrate which then subsequently acts as the electron donor for the chloro-respiration. The first step to enhance this type of degradation process is to create the proper conditions for the microorganism population to initiate reductive dechlorination. Once

that has been achieved, the microorganisms capable of dechlorination need an electron donor to complete the reaction.

The more highly chlorinated compounds (e.g., PCE and TCE) are most susceptible to reductive dechlorination because of their higher state of oxidation. ERD applications at other sites indicate that the groundwater environment is frequently not reducing enough (i.e., the oxidation-reduction potential is not negative enough) to allow for the complete degradation to occur and an accumulation of daughter products is observed (such as an accumulation of cis-1,2-DCE or VC). The later steps of this process, such as degradation of cis-1,2-DCE to VC, and degradation of VC to ethene, generally require more strongly reducing conditions in groundwater (typically in the range of -50 to -100 millivolts [mV] and lower) than do the initial degradation steps. Reductive dechlorination of the lesser-chlorinated VOCs, such as VC, has been observed at redox potentials corresponding to nitrate- and iron-reducing conditions. However, the reactions are most prevalent and faster under sulfate-reducing and methanogenic conditions. Figure 3-1 shows the primary degradation pathways of chlorinated ethenes by reductive dechlorination.

Existing studies described in the available literature indicate that the most common rate-limiting factors that result in slow, or little chlorinated compound degradation in groundwater include one or more of the following:

- 1) Lack of sufficient organic carbon in the site groundwater.
- 2) Relatively mild redox conditions (often slightly aerobic).
- 3) Presence of compounds competing for reduction such as sulfides.
- 4) Lack of the appropriate bacteria for the specific chlorinated compounds to be degraded (specifically *Dehalococcoides*, or very similar microbes capable of degrading cis-1,2-DCE and VC).

Degradation is often slowed due to the depletion of natural organic carbon in the groundwater and less than optimal reducing conditions present in the aquifer (redox above -50 mV). ORP measurements taken at various wells within the PCE plume at the Site show ORP measurements between -27 and +252 mV, with most readings¹ between +100 and +140 mV. Sulfate is present in groundwater at concentrations between 800 and 1,200 milligrams per liter (mg/L), which may initially slow the ERD process at the Site (see Figure 3-1 indicating that the sulfate reactions are likely to occur before the chlorinated volatile organic compound dechlorination reactions are completed).

3.1.1 Biostimulation Amendment

The goal of a biostimulation amendment is to provide a carbon source for driving the redox conditions lower and a hydrogen releasing compound that will serve as the electron donor. A wide variety of compounds have been used as biostimulation amendments for ERD applications. Some of the compounds include: sodium acetate, sodium lactate, sucrose, methanol, ethanol, yeast extract, sodium sulfate, soybean oil, or molasses. These materials have been successfully used in a variety of laboratory microcosm and field applications.

The considerations necessary in selecting a suitable biostimulation amendment include the nature, solubility and viscosity of the material. Food-grade materials (or equivalent purity) are typically preferred to ease the

¹ ORP measurements are from grab samples rather than a flow-through cell.

permitting requirements regarding an injected material. Other considerations include unit costs of the material, the rate of fermentation to generate hydrogen, potential proprietary and/or patent considerations, and the success of other field applications using the specific amendment.

A wide variety of substrates have been used to successfully enhance the in-situ biodegradation process. Several design/performance factors that need to be considered include:

- 1) Oxygen demand (chemical oxygen demand [COD] or biological oxygen demand [BOD]) of the substrate;
- 2) Theoretical mass of hydrogen that may be produced (based on reaction stoichiometry);
- 3) Actual efficiency of hydrogen generation;
- 4) Cost of the substrate; and
- 5) Rate and longevity of hydrogen generation.

The COD of the substrate is important because it helps to drive/maintain the redox condition of the aquifer to a low level where reductive dechlorination can occur. Within portions of the PCE plume, the conditions are not reducing; therefore the COD of the substrate is required because it represents the food source for biotic processes to change the aquifer to a lower redox condition. It is also important because it subsequently impacts the anaerobic fermentation process used to generate electron donors for the reductive dechlorination process.

3.1.2 Bio-Augmentation

Bio-augmentation is the process of injecting a microbial mixture into groundwater to aid in the dechlorination process of chlorinated compounds. When appropriate, trace levels of nutrients may also be added to promote accelerated bacterial growth and increase dechlorination rates. The typical trace nutrients added include nitrogen and phosphorus to support cell growth. Sometimes yeast extracts are added to provide additional enzymes.

Bio-augmentation is typically considered in an ERD project if specific areas show slower degradation rates (compared with other vertical intervals/areas) and/or the biodegradation appears to stall at a specific daughter product (i.e., TCE is reduced to cis-1,2-DCE however cis-1,2-DCE is not being reduced to VC). Bio-augmentation may be implemented at the Site because the COC concentrations are relatively elevated and it is prudent to implement all feasible steps to accelerate the dechlorination processes. However, the monitoring data will be used to evaluate whether cis-1,2-DCE stall is occurring and will guide decision-making for implementing bio-augmentation. For example, if PCE and TCE are degrading all the way to ethene, it may not be necessary to implement bio-augmentation.

3.2 Permits

This section describes the permits anticipated/required to implement and complete the project. The Matrix-CALIBRE Team will obtain the permits before the relevant portion of the work is undertaken. If other permits are identified by ADEQ and/or local municipality they will be obtained.

- 1) An Underground Injection Control (UIC) registration will be filed with U.S. Environmental Protection Agency (EPA) Region 9. Information about the UIC process is located at:
<http://www2.epa.gov/uic/forms/underground-injection-wells-tregistration>.
- 2) A notice of intent to drill will be filed with the Arizona Department of Water Resources in accordance with the general information and forms listed at:
<http://www.azwater.gov/azdwr/WaterManagement/NOI/documents/PermitsFormsApplicationsNOI.htm>

3.3 Well Installation

As noted in the CSM, added data are necessary to bound the spatial position and vertical interval of the targeted plume treatment area. All new wells will be installed with two objectives; 1) provide data to better characterize the plume position, and 2) start ERD treatment near the leading edge of the plume in areas expected to have the highest VOC concentrations. Six new injection wells will be installed (see Figure 3-2) to implement ERD treatment in the area of the Site. The areas covered represent the zones anticipated to have the highest VOC concentrations.

The new injection wells will be identified as ERD-1, ERD-2, ERD-3, ERD-4, ERD-5, and ERD-6. The proposed well depth and order of drilling are indicated in the Table 3-1 along with notes related to the well.

Each well will be completed with a flush mount monument. SOPs for well drilling and geological logging during well drilling are included in Attachment A.

Prior to drilling, a utility clearance will be ordered and completed for the drill locations. The wells will be drilled using a sonic drill rig, based on prior drilling experience at the Site. Four inch diameter schedule 40 polyvinyl chloride casing will be used to complete the wells. Each well will be constructed with multiple segmented screens to allow injection at depth-specific intervals as shown in Figure 3-3. The annular space of the wells will be sealed at the surface in compliance with Arizona well drilling regulations. After the wells are installed, they will be developed by the driller as described in the SOPs (Attachment A).

3.4 ERD Implementation

ERD will be implemented in two stages. In the first stage, a sugar-based substrate solution will be added to each of the new wells. The goal is to achieve approximately 1,000 mg/L (0.1 percent) sugar solution in an assumed radius of 25 ft around each well. This equates to injecting approximately 300 gallons of 10% solution per 10 ft of well screen (600 gallons would be injected in a 20 ft well screen and 900 gallons for a 30 ft well screen).

Groundwater samples will be collected from the new wells before substrate injection to characterize baseline conditions as described in Section 4. After approximately three months, the same wells will be sampled a second time, followed by a repeated substrate injection.

If monitoring data indicate that bio-augmentation may be helpful in promoting accelerated or more complete dechlorination, it will be implemented using microbial cultures (*Dehalococcoides*) purchased from a

vendor (e.g., KB-1 from Sirem, BDI-PLUS from Regenesys, or BAC-9 from EOS Remediation²). On other projects, the bio-augmentation has been completed by extracting groundwater from a well within the same plume that is known to contain *Dehalococcoides* and injecting that water into wells or areas that are experiencing slower dechlorination rates because of insufficient microbial activity. This alternate bio-augmentation procedure may be useful at this Site at a later time.

² All of these vendors supply bio-augmentation cultures containing *Dehalococcoides* which have been used successfully on multiple projects.

4.0 OPERATION AND MAINTENANCE AND PERFORMANCE MONITORING

This section includes a summary of the O&M requirements for remedial actions that involve treatment of water and details regarding the proposed groundwater monitoring associated with the ERA.

4.1 Operation and Maintenance Requirements

As described in Section 1.2, an O&M Plan is required for ERAs that involve treatment of water. Pursuant to A.A.C 18-16-422.E, the O&M plan shall include:

- 1) Certification by the Department that the elements of the operations and maintenance plan adequately protect public health against treatment system failure.
- 2) A schedule and plan for water quality monitoring.
- 3) A requirement that affected water providers receive a copy of the completed application and a copy of the final permit for any National Pollutant Discharge Elimination System (NPDES) permit for the Site.
- 4) A process for the treatment system operator to promptly notify potentially affected water providers of a failure of a key treatment system component that could affect the quality of a discharge of treated water.
- 5) For a discharge to a water of the United States, operational, maintenance and management practices to assure achievement of water quality discharge standards established in 18 A.A.C. 11 prior to the point of discharge for those VOCs which are contaminants of concern at the Site.

Of the five requirements listed above, items 3, 4, and 5 do not apply because there is no discharge associated with the in situ treatment described in this Plan. The monitoring plan and schedule, per requirement 2, are described in a subsequent section.

4.2 Operation and Maintenance Procedures

ERD is an in-situ treatment process and the O&M elements of the remedial action involve substrate injection, monitoring, and remedial optimization to adjust/modify geochemical conditions (to accelerate/optimize the degradation processes). The ERD O&M will be implemented in stages. In the first stage, a sugar-based substrate solution will be added to each of the new injection wells. The goal is to achieve approximately 1,000 mg/L (0.1 percent) sugar solution in an assumed radius of 25 ft around each of the injection wells. The volume of substrate required for injection at each well will be determined prior to arriving onsite based on the vertical plume interval to be treated (as discussed in prior section 3.4). The substrate will arrive at the site and will be diluted to approximately 10,000 mg/L in a tank on a truck or at the Facility depending on the availability of parking at each well location. The substrate will be injected at specific depth intervals using a drop tube and packers following the well construction detail shown in Figure 3-3 and as further described in Appendix A, Enhanced Reductive Dechlorination (ERD) Substrate Injection SOPS and Contingency Plan, CALIBRE Standard Operating Procedures Addendum. .

Groundwater samples will be collected from the new wells prior to injection. After approximately three months, the same wells will be sampled a second time, followed by a repeated substrate injection and may include bio-augmentation. This second round of sampling will include analysis for VOCs, total organic carbon

(TOC), and sulfate. The TOC data are used as one measure regarding when added substrate injection is necessary.

If it is to be used, the bio-augmentation inoculum will be prepared and injected in accordance with the vendor's specifications. Typically the inoculum is delivered in a 20 liter keg that must be diluted/prepared with "oxygen-free" water before it is injected into the subsurface. Prior to mixing with the inoculum, a 55-gal drum of water is sparged with nitrogen (equivalent to a fish tank aerator with nitrogen sparging) in order to ensure that the water has reached the desired anoxic condition.

As noted previously, the bio-augmentation may also be completed by extracting groundwater from a well within the same plume that is known to contain *Dehalococcoides* and injecting that water into wells or areas that are experiencing slower dechlorination rates because of insufficient microbial activity. This alternate bio-augmentation procedure may be useful at this Site at a later time.

4.3 Description of Groundwater Monitoring

An initial round of samples will be collected shortly after the ERD wells are installed to focus the ERD efforts in targeted areas/vertical intervals and to define baseline conditions. This will include depth-specific samples collected from MW-21B near the top and bottom of the well screen. During the initial event, samples will be collected from each screen interval in the new wells. These results will be reviewed to decide which intervals will be targeted for ERD. Subsequently, groundwater samples will be collected periodically to evaluate the effectiveness of the ERD treatment. These periodic sample results will be collected periodically to evaluate groundwater conditions both in terms of COC concentrations and indicators of the progress of ERD. These samples will be collected approximately every three months. The frequency may be adjusted depending on the variability of the sampling results over time.

After each sampling event, the results will be reviewed and the subsequent ERD event will be refined as appropriate. For example, if the TOC decreases to approximately 100 mg/L in a specific well or zone within a well, an additional injection of amendments will be proposed and implemented. If indications of cis-1,2-DCE stall are observed, a sample will be collected for microbial census purposes to investigate whether the appropriate microbes are present to dechlorinate cis-1,2-DCE to VC and finally ethane.

Samples will be collected using either passive diffusion bags (PDBs) or dedicated downhole pumps for each well (see SOPs in Attachment A). The decision between PDBs or downhole pumps will be based on the timing and staff access for sampling. If used, the down-hole pumps will be a Waterra foot-valve set-up. The wells that will be sampled are shown in Table 4-1. The list of wells to be sampled may be modified after the first sampling event depending on the results of that sampling.

All groundwater samples will be analyzed for VOCs and for degradation/attenuation parameters, including TOC and sulfate.

Analytical methods, sample container types, holding times, preservatives, and target reporting limits for the sample analyses are summarized in Table 4-2. All sample containers will be laboratory-prepared and pre-cleaned. The laboratory will provide pre-preserved containers for analytes that require preservatives (VOCs, selected MNA parameters, others).

All analytical methods/procedures used will follow methods presented in the most current version of EPA Test Methods for Evaluating Solid Waste (SW-846), where applicable. The laboratory analysis will be completed by an Arizona accredited/ certified laboratory for the specified analyses.

5.0 GROUNDWATER SAMPLING PROCEDURES

The groundwater sampling will follow the procedures presented in the SOPs (Attachment A) and include the following steps: wellhead inspection, water level measurement, field parameter measurements, and sample collection for laboratory analysis. Groundwater sampling will be conducted by deploying and subsequently retrieving PDBs, if they can be successfully deployed. Otherwise, a dedicated pump is the preferred sample collection method (see SOPs in Attachment A). The PDBs will be lowered into the well on a pre-measured nylon cord so that the PDB is located in the middle of the screened interval of each well. The PDBs will be deployed for at least ten days prior to retrieval. Water samples for census testing will be collected with a HydraSleeve™ to obtain sufficient sample volume, and filtered according to laboratory-specified procedures.

5.1 Sample Identification/Numbering

All samples will be assigned a unique identification code based on a designation scheme that allows for quick determination of both sample location and sampling date. Each sample label will be affixed to the bottle and covered with clear tape. Tape is not required if waterproof labels are used. A sample tracking record will be kept as each sample is collected. The following information will be recorded: location, matrix, sample number, and observations.

Sample identification codes will consist of four components separated by a dash. These components are site identification, well identification, sample depth, and sample date. The sample designation scheme is as follows:

Site Identification Code – Well Identification – Sample Depth - Sampling Date (month/day/year format)

For example, a sample taken from the Site, at well location ERD-1 and sampled on October 5, 2016 would use the identification/label:

20&F-ERD-1-120-100516

Sample numbers will be recorded in the field notebook, on sample container labels, the groundwater sampling form, and chain-of-custody forms. Other information recorded on the sample container label will include:

- time and date of sample collection,
- initials of sampler(s),
- laboratory analyses to be performed, and
- preservatives used.

Additional detailed procedures regarding labels, sample handling, chain-of-custody, custody seals, and sample shipping are described in the SOPs (Attachment A).

5.2 Quality Assurance/Quality Control

5.2.1 Project Quality Assurance/Quality Control

All field activities will be conducted in accordance with the quality assurance /quality control (QA/QC) requirements described in the programmatic QAPP (Matrix-CALIBRE, 2014a). Laboratory QA/QC, such as number and type of QC samples, control limits, and corrective actions, will be in accordance with the laboratory's Quality Assurance Manual. Laboratory quality control samples for analysis will include surrogate spikes, method blanks, and matrix spikes/matrix spikes duplicates. Precision will be estimated from the results of blind field and laboratory duplicates, and duplicate matrix spikes. Field QC samples are described below.

5.2.2 Field Sampling Quality Assurance/Quality Control

Several types of QA/QC samples will be analyzed to document the quality of the sampling program in accordance with the project QAPP. These include duplicate samples, trip blanks, and matrix spike/matrix spike duplicates (MS/MSD). Each type of QA/QC sample will be used to evaluate different phases of the sampling and analytical process.

Duplicate Samples: Laboratory and field sampling precision will be evaluated by collecting blind field duplicate samples. Because of the small sample size, one field duplicate sample will be collected per event. Field duplicates will be collected and analyzed for constituents which are compared to regulatory criteria (i.e., analytes which have an AWQS or other relevant comparison criteria).

Trip Blank Samples: The potential for VOC contamination from the ambient air or during transport will be evaluated using trip blank samples. Trip blanks will originate at the laboratory and be labeled upon arrival at the Site. Trip blank samples will accompany one cooler of samples during sampling and shipping for each day during a sampling event.

MS/MSD Samples: Potential interferences from the sample matrix will be evaluated with MS/MSD samples. Triplicate sample volumes will be collected at selected locations from the planned sampling list. Because of the small sample size, one MS/MSD sample will be collected for each sampling event. MS/MSD samples will be analyzed for the same constituent list as the original sample.

5.3 Field Documentation and Sample Management

Sample documentation and control are required to ensure that the data are accurate and to verify that appropriate field (and data review) procedures are followed during all phases of the project. The field procedures to be followed for documentation, control, and transport of environmental samples are described in this section.

5.3.1 Field Documentation

Field notes will be kept in bound field logbooks and entries will be made with indelible ink. Logbook pages will not be removed from the logbook. Incorrect entries will be noted by striking the incorrect entry with a single line, adding the correct entry, and dating and initialing the change. Field logbook entries will include factual information (free of conjecture and subjective language) and include sufficient detail such that

another person (not on the field sampling team) reading logbook entries is able to understand the sampling situation based on the recorded information. Sampling information that should be entered into the field logbook includes the following:

- Date and time of sampling
- Sampling method (PDB, purging, grab, or other)
- Weather conditions
- Names or initials of sampling personnel
- Well or location identification number
- General condition of well (if noteworthy)
- Static water level
- Total depth of well
- Depth of sample collection
- Manufacturer, model number, serial number, and calibration notes for any instrument used for static water level measurement, health and safety, or field parameter analysis
- Miscellaneous comments or observations (if applicable)
- Health and safety monitoring instrument readings (if applicable)

5.4 Sample Chain-of-Custody and Transport

Sample possession will be traceable from the time of sample collection until receipt of samples at the analytical laboratory. Sample chain-of-custody will be documented following the procedures outlined below.

5.4.1 Field Custody

Samples collected will be in the custody of the field sampler(s) from the time of sample collection until the samples are transferred to the laboratory (or to a courier/delivery service). Groundwater samples will be stored in coolers with sufficient bagged ice to maintain an internal temperature of 4 degrees Celsius.

5.4.2 Sample Chain-of-Custody and Transport

A chain-of-custody record will accompany all samples. When transferring sample custody, the individuals relinquishing and receiving the samples will sign, date, and note the time of transfer on the chain-of-custody record.

Samples that are hand-delivered to the laboratory may use one chain-of-custody record for all the coolers delivered. Hand-delivered sample coolers do not need to be sealed with fiber tape or custody seals. All sample transfers and deliveries will follow standard chain-of-custody procedures. If sampling is conducted on days when the laboratory is closed, the samples will be hand-delivered or delivered via courier the following business day.

One or more analytical laboratories may be used and the selected laboratory may change depending on various project constraints/conditions. The selected laboratory, shipping address/shipping labels, point of contact and phone number must be provided to the field team prior to mobilization. This will typically be completed with the sample bottle order.

5.4.3 Planned Data Management and Reporting

Laboratory analyses and data packages generated will be equivalent to a Tier II data report. The laboratory data package will undergo data validation applicable to the data package provided (Tier 1A/1B validation). The data will also be received from the laboratory as an Electronic Data Deliverable (EDD). The EDD will be imported directly into the project data management system to minimize the potential for data entry/transcription errors. All project data reports, evaluation, trend analysis, or any other uses of the data will import the appropriate data set(s) from the data management system. The EDD will be provided to ADEQ periodically to update their database, as required.

The results of sampling events will be presented in a Summary Monitoring Report that includes description of field sampling activities with any deviations from this Plan. The report will include summary tables of field parameters collected (depth to water, any water quality parameters), along with the list of wells sampled, analysis conducted, and summary tables and figures presenting analytical results. The report will also summarize any deviations from the Plan, specifically including a summary of any wells that could not be sampled and the reason why (e.g., the well is dry, access restrictions, damage to well, or other).

5.5 Decontamination and Disposal of Investigation Derived Waste

This section describes the procedures that the field crew will use to decontaminate sampling equipment to reduce the possibility of cross contamination during sampling activities. There is also a discussion of the procedures that the field crew will follow to manage investigation-derived waste (IDW).

5.5.1 Decontamination

The sampling methods described above use dedicated sampling equipment to the extent possible and avoid reusing sampling equipment. This minimizes the potential for cross contamination between wells and reduces the need to decontaminate sampling equipment. Any equipment that comes in direct contact with sample media, sample containers, or the inside of a monitoring well will be either dedicated equipment (assigned to and used at only one well) or single-use disposable equipment that is replaced between each sampling location. Some equipment, such as water level indicators, will be used at more than one monitoring well and will require decontamination after each use. If the sampling equipment is not single-use disposable equipment, or dedicated equipment, it will be decontaminated between each sampling event as described in the following sections.

5.5.2 Aqueous Sampling Equipment Decontamination

If non-dedicated, multiple-use sampling equipment is used for groundwater sampling, it will be decontaminated prior to use and between each sample according to the following steps:

1. Wash in a solution of Liquinox™ (or equivalent) and potable tap water
2. Rinse with potable tap water
3. Rinse with distilled water

If non-dedicated sampling equipment such as a pump, tubing or a flow-through cell is used which is also located ahead of the sampling port, it will be decontaminated and an equipment blank sample will be

collected (after decontamination). As noted above, this will only apply to non-dedicated sampling equipment used within the flow stream of the sample to be collected (to identify the potential for equipment cross contamination). An equipment blank sample will be collected daily (if required). A water level indicator (E-tape) will be used at each well and decontaminated after each use. Decontamination of the E-tape is simple and effective; an equipment blank sample will not be collected for the E-tape, it is not used within the flow stream of the samples to be collected.

5.5.3 Management of Investigation-Derived Waste

The driller will place soil cuttings from well drilling in roll-off bins during drilling activities. Once a roll-off is full it will be transported for temporary storage to the paved area on the east side of the Houston International facility, located at 655 E. 20th St. The soil will be sampled for disposal characterization purposes and disposed of accordingly. It is likely that the soil will not be hazardous and can be disposed of at a landfill without a manifest. If the soil cuttings are determined to be hazardous materials, ADEQ will be contacted to sign the hazardous waste manifest.

Purge water, decontamination water, and other IDW will be collected in containers (drums or smaller tanks with sealable lids) and consolidated into a temporary storage tank. All liquid IDW will be transferred to a temporary storage tank on the Houston International property and a vendor will be used to haul the water offsite for treatment and disposal. As needed by the treatment vendor, a waste characterization sample (of the liquid IDW) will be collected and submitted for laboratory analysis. After reviewing the analytical results, the IDW will be disposed of in compliance with applicable laws/policies.

Further details on IDW handling and management are provided in the SOPs (Attachment A). If any IDW is to be managed as a regulated waste it will be stored in Department of Transportation approved containers.

6.0 HEALTH AND SAFETY

6.1 Health and Safety Plan

All field activities will be conducted in accordance with the project HASP. A designated Health and Safety supervisor will be on site during all field activities to ensure compliance with the HASP and resolve any safety related issues. The project HASP is included as Attachment B. The HASP has been prepared to meet or exceed the minimum requirements established in Occupational Safety and Health Administration Safety and Health Standards (29 CFR 1910).

6.2 Personal Protective Equipment

It is anticipated that work at the Site will be conducted in modified Level D personal protective equipment that includes the following components:

- Steel-toed, steel-shank leather or rubber boots
- Hard hat (during drilling operations)
- Safety glasses or equivalent
- Nitrile gloves, or equivalent

A new pair of gloves will be used for sample collection at each well sampled. The HASP (Attachment B) includes more details on safety procedures and personal protective equipment.

7.0 PROJECT TEAM, RESPONSIBILITIES AND DRAFT SCHEDULE

The key project team members and their responsibilities are presented in the Table 7-1 and the Project Management Plan previously prepared for this project by the Matrix-CALIBRE Team (Matrix-CALIBRE 2014b).

A project schedule is shown in Figure 7-1. The schedule is aggressive and specific milestones/elements may change based on permitting, subcontractor (driller) availability, weather and other factors.

Changes and details of the projects schedule will be noted in the weekly reporting associated with the Weekly Risk Report.

8.0 REFERENCES

Dickinson, J. E., Land, M, Faunt, C.C., Leake, S.A., Reichard, E.G., Fleming, J.B, and D.R. Pool, 2006.

Hydrogeologic Framework Refinement, Ground-Water Flow and Storage, Water-Chemistry Analyses, and Water-Budget Components of the Yuma Area, Southwestern Arizona and Southeastern California, United States Geological Survey, Scientific Investigation Report, 2006-5135.

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Matrix-CALIBRE, 2016a. Feasibility Study Report. 20th and Factor WQARF Site, Yuma, Arizona. August 11, 2016.

Matrix-CALIBRE, 2016b. 2016 Groundwater Monitoring and MW-31B Well Installation Report. 20th and Factor WQARF Site, Yuma, Arizona. June, 2016.

Tetra Tech, 2014. Remedial Investigation Report 20th Street and Factor Avenue WQARF Site. Yuma, Arizona. June 2014.

TABLES

Table 3-1 Proposed Total Depths and Screen Intervals for ERD Wells

Well	Planned Total Depth (ft)*	Screen Intervals (ft)*	Notes Regarding Sampling Objective and Area Targeted for Treatment
ERD-1	185	110-130 135-165 170-185	This well location is 180 ft up gradient (east) of MW-18B and will provide lithologic and contaminant distribution data (both vertical and spatial) between MW-18B and MW-8B. ERD treatment up gradient of MW-18B including areas just south of MW-18B, which is the well with highest current PCE concentration and screened from 137-147 ft bgs.
ERD-5	180	115-130 135-150 155-175	This well location is on S. 2 nd Avenue and will provide lithologic and contaminant distribution data (both vertical and spatial) between MW-18B and MW-21B; Start ERD treatment up gradient of MW-21B, which is the well with highest current TCE concentration and screened from 161-201 ft bgs.
ERD-6	185	105-115 120-140 165-185	This well location is near the MW-21 A,B,C cluster. One goal of the well is to clarify the extent of Clay A, which was identified at different intervals and thicknesses in MW-21B and MW-21C. The proposed TD for ERD-6 is intended to drill through Clay A.
ERD-3	180	110-130 135-155 160-180	This well location is on S. 1 st Ave, approximately 250 ft north of MW-18B. Data from this well is intended to help define a northern bound to the extent of contamination in the B-zone. ERD treatment up-gradient of MW-21B.
ERD-4	180	110-130 135-155 160-180	This well location is on S. 2 nd Avenue and will provide lithologic and contaminant distribution information between MW-18B and MW-21B. ERD treatment up-gradient of MW-21B.
ERD-2	180	110-130 135-155 160-180	This well location is on S. 1 st Ave, approximately 55 ft northeast of MW-18B and is intended to treat contamination in the vicinity of MW-18B.

* The total depth and screen interval of each well may be adjusted based on lithologic logging conducted while drilling the wells.

Table 4-1 Wells to be Sampled to Evaluate ERD Performance

Well	VOCs	Field Parameters	Selected Attenuation Parameters
ERD-1	X	X	X
ERD-2	X	X	X
ERD-3	X	X	X
ERD-4	X	X	X
ERD-5	X	X	X
ERD-6	X	X	X
MW-18A	X	X	X
MW-18B	X	X	X
MW-21A	X	X	X
MW-21B	X	X	X

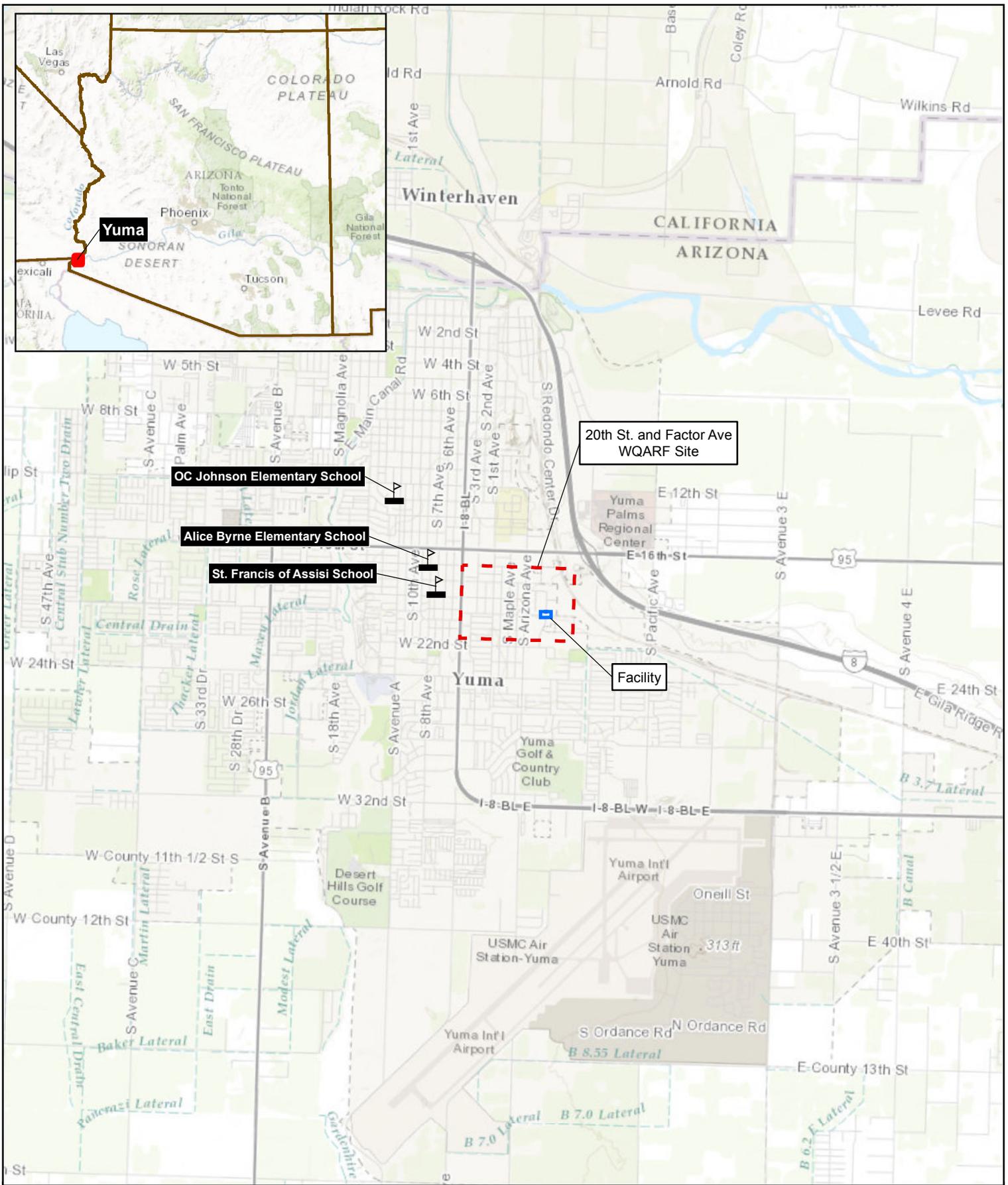
Table 4-2 Analytical Methods, Holding Times, Containers, Preservation, and Target Reporting Limits

Analysis	Analytical Method	Holding Time	Sample Container (preservative)	Target Reporting Limit	Notes
VOCs	8260B	14 Days	3-40 ml, glass vials (cool to 4°C, HCl to pH _≤ 2)	0.5 µg/L	Pre-preserved by laboratory
Dissolved Oxygen	Field Water Quality Instrument	-	-	-	-
Redox Potential	Field Water Quality Instrument	-	-	-	-
pH	Field Water Quality Instrument	-	-	-	-
Total Organic Carbon	SM5310C	28 days	250 ml-amber (cool 4°C, H ₂ SO ₄ to pH ≤ 2)	1.0 mg/L	Pre-preserved by laboratory
Sulfate	SM9056A	28 days	500-ml HDPE	28 days	??
Bio-Dechlor Census Test	real time polymerase chain reaction	24 hours for filtration	1 L HDPE (cool 4°C)	~10 ² organisms/ml	The lab also has “bio-trap filters” that may be used

Table 7-1 ADEQ and Matrix-CALIBRE Program/Project Personnel and Responsibilities

Personnel	Position	Responsibility
Kevin Snyder	ADEQ Project Manager	Overall Project Management and Review
Mike Gronseth	Program Manager	Program Management
Tom McKeon	Project Manager	Task Management and Oversight
Dan Miller, P.G.	Geologist	Management of Field Operations/Drilling
Justin Neste	Site Health and Safety Officer	Health and Safety and Management of Field Operations/Sampling

FIGURES



Drawn By: JKC
 QC'd By: CHW
 Drawing Date: 5/2/2016

Legend

- 20th St. and Factor Ave WQARF Site (Approximate Boundary)
- Schools

WQARF = Water Quality Assurance Revolving Fund

Site Location Map

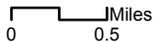
Early Response Action Work Plan
 20th Street and Factor Avenue
 WQARF Site



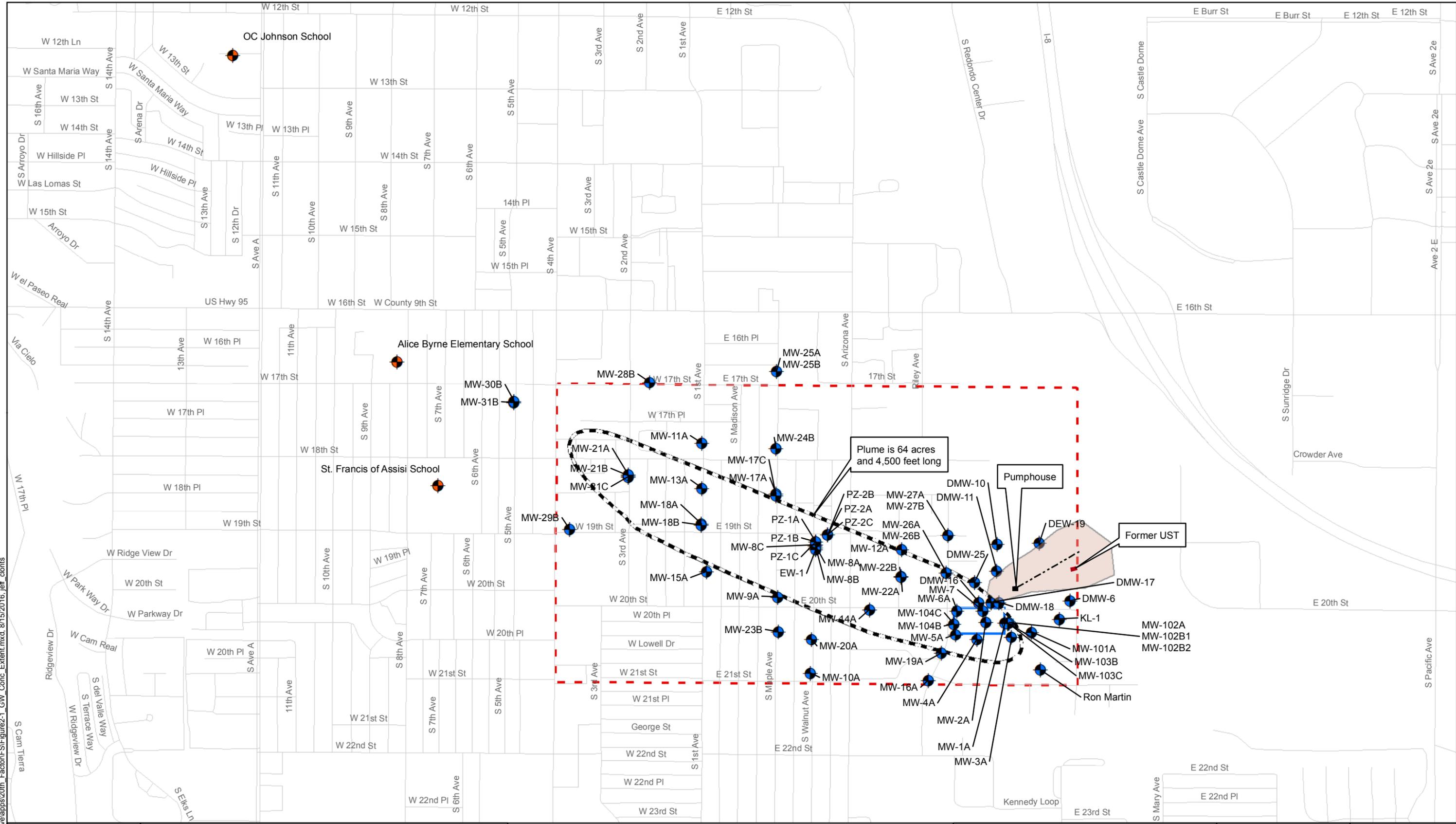


Figure 1-1





FILE C:\99_projects\AQD\erawp\figs_Sample_Location.mxd 11/10/2014 wkroon_whoar



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Drawn By: JKC
 QC'd By: CHW
 Drawing Date: 5/2/2016

Legend	<ul style="list-style-type: none"> Monitoring Well Irrigation Well Facility Extent of Groundwater Contamination (2016) 	<ul style="list-style-type: none"> 20th St. and Factor Ave WQARF Site (Approximate Boundary) Pumphouse Former UST 4" Diesel Pipeline Approximate Boundary of Dieselville Site 	<ul style="list-style-type: none"> Streets WQARF = Water Quality Assurance Revolving Fund
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Extent of Groundwater Contamination

Early Response Action Work Plan 20th Street and Factor Avenue WQARF Site

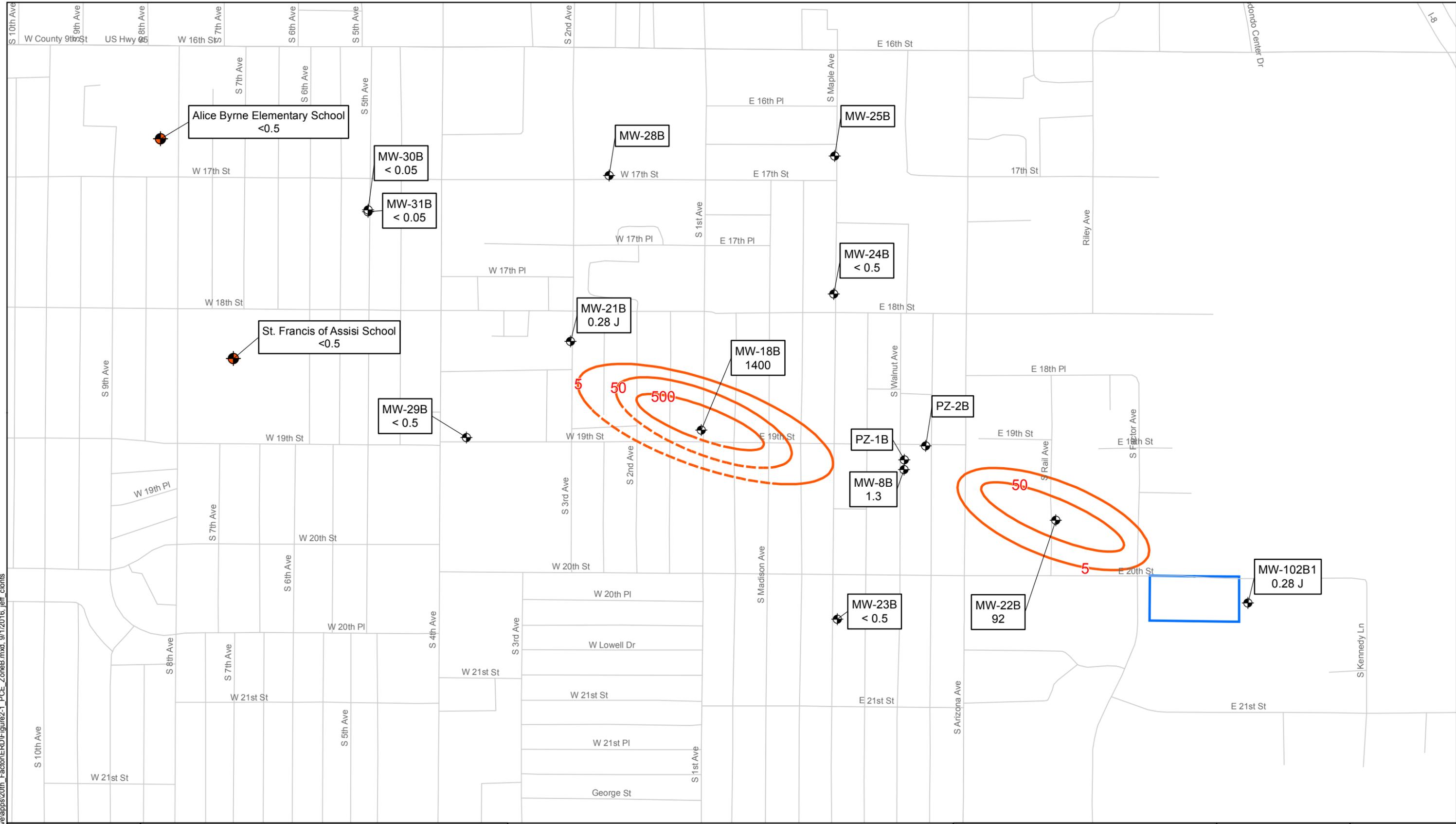
Arizona Department of Environmental Quality

MATRIX DESIGN GROUP

CALIBRE

0 400 800 Feet

Figure
1-2



FILE: G:\gis_projects\ADEC\active\apps\20th_Factor\ERD\Figure2-1_PCE_ZoneB.mxd, 9/1/2016, jeff_cblnts

Drawn By: JKC
 QC'd By: CHW
 Drawing Date: 5/2/2016

Legend

- Monitoring Well (Zone B)
- Irrigation Well
- PCE Concentration (ug/L)
- Facility
- Streets

Notes:
 ug/L = micrograms per liter
 PCE = Tetrachloroethene
 WQARF = Water Quality Assurance
 Revolving Fund
 AWQS = Aquifer Water Quality Standard
 AWQS = 5 ug/L
 J = estimated concentration

PCE in Zone B (February 2016)
 Early Response Action Work Plan
 20th Street and Factor Avenue
 WQARF Site

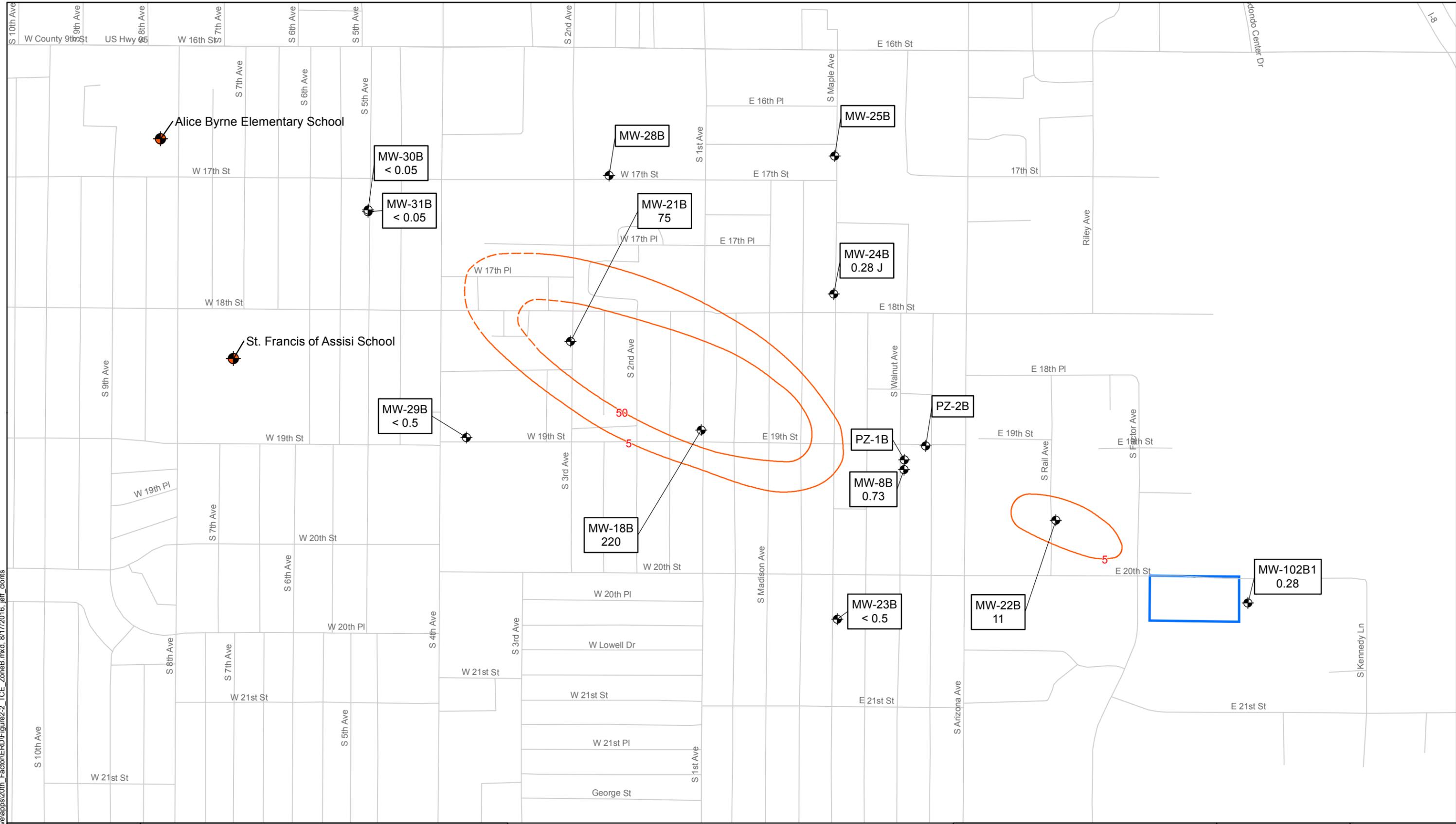
ADEQ
 Arizona Department of Environmental Quality

Matrix
 DESIGN GROUP

CALIBRE

0 225 450 Feet

Figure
 2-1



FILE: G:\gis_projects\ADEC\active\apps\20th_Factor\ERD\Figure2-2_TCE_ZoneB.mxd, 8/17/2016, jeff_clovis

Drawn By: JKC
 QC'd By: CHW
 Drawing Date: 5/2/2016

Legend

- Monitoring Well (Zone B)
TCE Concentration (ug/L)
- Irrigation Well
- Facility
- Streets

Notes:
 ug/L = micrograms per liter
 TCE = trichloroethene
 WQARF = Water Quality Assurance
 Revolving Fund
 AWQS = Aquifer Water Quality Standard
 AWQS = 5 ug/L

TCE Concentration (ug/L)
(dashed where inferred)

TCE in Zone B (February 2016)
 Early Response Action Work Plan
 20th Street and Factor Avenue
 WQARF Site

Arizona Department of Environmental Quality
 Matrix DESIGN GROUP
 CALIBRE

0 200 400 Feet

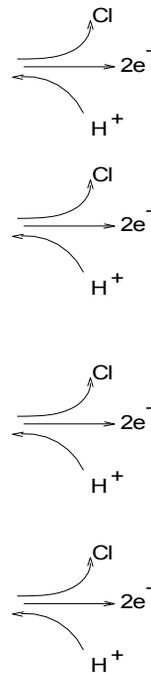
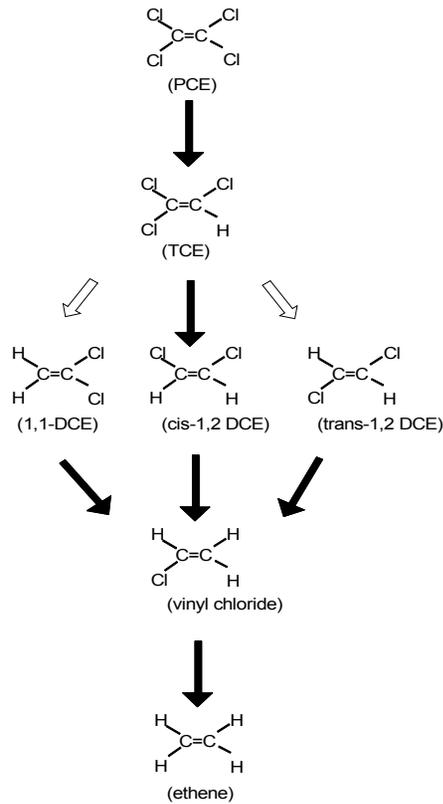
Figure
2-2

Chlorinated Compound

Biologically- mediated reaction

Enabling Aquifer Condition

Typical Redox Energy Level for Optimum Degradation (see note below)



Anaerobic Denitrification

Redox measures +250 to +100 mV

Anaerobic Iron (III) reduction

Redox measures +100 to 0 mV

Anaerobic Sulfate reduction

Redox measures 0 to -200 mV

Methane fermentation
Methanogenesis

Redox measures -200 mV and lower

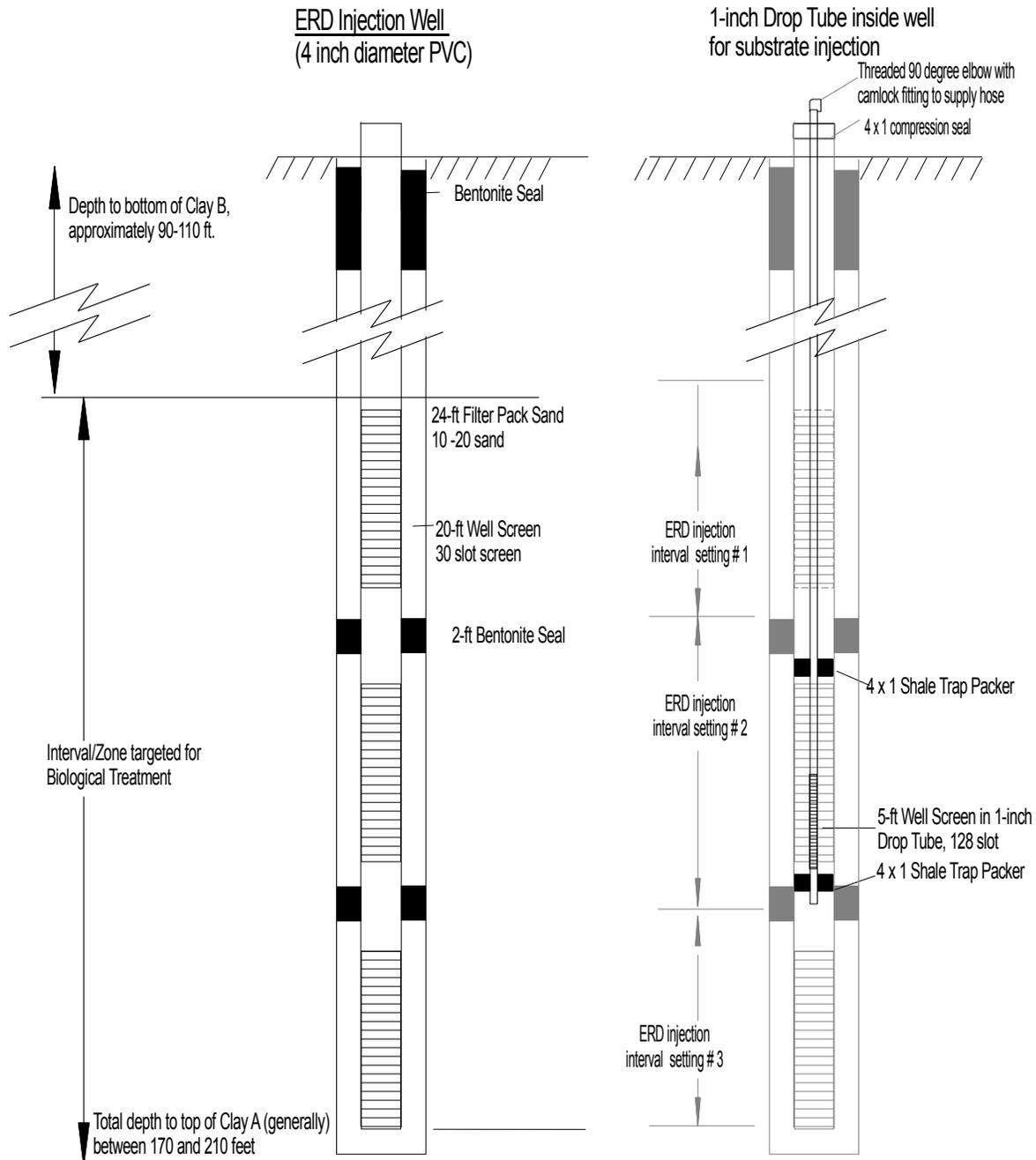
Primary degradation pathway
 Minor pathway

Note: a wide range of ORP values have been cited in prior studies; values presented here are general ranges from prior work (example reference sources include: Faris and Vlassopoulos [2003] and Wiedemeier et al. [1998])



Early Response Action Work Plan
20th St. and Factor Ave. WQARF Site
Yuma, AZ

Figure 3-1
Primary Degradation Pathways
of Chlorinated Ethenes by
Reductive Dechlorination



The ERD Injection well design is adjustable so that different intervals may be injected combined, separately, or sequentially into one or more specific target intervals. The drop tube (right hand side figure) may be raised or lowered and the packer interval may be adjusted to one or more screen sections of the ERD injection well for varying permeability. As depicted above, ERD drop tube is configured for delivery over interval setting # 2.

Details are conceptual design, actual details will vary and be adjusted based on lithology and target screen depth



Early Response Action Work Plan
 20th St. and Factor Ave. WQARF Site
 Yuma, AZ

Figure7-1
 Project Schedule

ATTACHMENT A
STANDARD OPERATING PROCEDURES

Attachment A

Standard Operating Procedures

Enhanced Reductive Dechlorination (ERD) Substrate Injection SOPs and Contingency Plan
Contingency Plan and Emergency Procedures
Decontamination of Sampling Equipment
Direct-Push and Monitoring Well Groundwater Sampling
Groundwater Sampling
Low-flow Groundwater Sample Collection
Passive Diffusion Bag Samplers
Photoionization Detector Calibration and Use
Correction Factors, Ionization Energies, and Calibration Characteristics
Sample Packaging and Shipment
Soil Sampling
Collecting and Preparing Soil Samples for VOC Analysis
Enhanced Reductive Dechlorination Substrate Injection SOPs and Contingency Plan
Vapor Sampling
Well Construction and Development
Well Drilling, Construction, and Sampling in Roadways
Utility Clearance required prior to intrusive investigation or remediation activities

**ENHANCED REDUCTIVE DECHLORINATION (ERD) SUBSTRATE
INJECTION SOPS AND CONTINGENCY PLAN
CALIBRE STANDARD OPERATING PROCEDURES ADDENDUM**

1.0 POLICY

It is the policy of CALIBRE that any individual engaging in ERD injections will abide by the procedures outlined in this document. These procedures include project specific addendums to the CALIBRE Contingency Plan and Emergency Procedures Standard Operating Procedures and are designed to meet or exceed applicable Occupational Safety and Health Administration (OSHA) standards for safe work practices.

2.0 PURPOSE

The following is an amendment to the Contingency Plan and Emergency Procedures (CALIBRE 2004) specifically relating to ERD operation and potential spills of ERD injection materials (specifically water with sugar, carbohydrates or chase water used to flush the wells after substrate injection). The amendment provides specific detailed steps to be followed in the case of a large or small spill, within or outside of the containment area. For each scenario, the following response actions will be taken. Prior to any work being conducted the following procedures will be followed by all on-site personnel.

1. All personnel must read and discuss this contingency plan prior to any day of work/activity in which fluids are to be processed/handled or injected.
2. Storm drains near the work area will be identified.
3. Storm drain covers will be located. These will be placed on the storm drains before work proceeds except in inclement weather (significant precipitation where the covers would cause extensive pooling of water) when they will be kept close at hand.
4. Assemble all required spill control supplies and verify that all are functional.
5. Verify that power source is activated; find circuit breakers (for reset if required) or backup power.

3.0 SPILL CONTROL SUPPLIES

Shop vac
Extension cord(s)
Power supply
Multiple 5 gallon buckets
Broom
Storm drain covers
Flat-head shovel
Absorbent media (kitty litter)
Absorbent pads
Open top drum(s)
Wrench to open drums

4.0 PLANNING FOR POTENTIAL SPILL SCENARIOS

4.1 Small Spill within Containment Area

1. Stop the flow of the spill by shutting the valve or up-righting the hose or bucket from which the solution/fluid is coming.
2. Use the shop vac to clean up any remaining solution/fluid.
3. Repair or tighten any portion of the system that caused the small spill.

4.2 Large Spill within Containment Area

1. Stop the flow of the solution by unplugging the pump and closing valve at outlet of the Baker tank.
2. Place a bucket or other container under the spill to capture it
3. Vacuum spilled liquid and return to Baker tank, or other secure vessel.

4.3 Small Out of Containment Area Spill

1. Slow or stop the flow of the solution/fluid using the valve adjacent to the flow meter.
2. Sweep the solution/fluid back into the well head.
3. Vacuum any remaining solution/fluid.
4. Return solution/fluid to the system.

4.4 Large Out of Containment Area Spill

1. Stop the flow of the solution by unplugging the pump and closing the valve at outlet of the Baker tank.
2. Cover all storm drains with appropriate storm drain covers if not already done.
3. Vacuum spilled liquid and return to Baker tank or other secure vessel.
4. Call assigned Boeing project personnel to notify them of spill.

4.5 Spill that Discharges to Storm Drain

1. Stop the flow of the solution by unplugging the pump and closing valve at outlet of the Baker tank.
2. Cover all storm drains with appropriate storm drain covers if not already done.
3. Contact F&B office to notify them of the incident.
4. Vacuum spilled liquid and return to Baker tank or other secure vessel.
5. Call assigned Boeing project personnel to notify them of spill.

5.0 OPERATING PROCEDURES FOR ERD INJECTIONS

5.1 Startup Steps

1. Check that all cam-locks and hoses are fully connected.
2. Check that all well head connections are setup and tight.

3. Check that all hose-clamps are tight.
4. Verify that the correct filters are placed in housings (typical 10 micron or 50 micron).
5. Verify that all flow meters are zeroed.
6. Close all valves located to the left of flow meters, reopen a small fraction (~ 1/16 to 1/8 of a turn from the seated-valve condition).
7. Open valve at outlet of Baker tank.
8. Turn on pump.
9. Check and adjust flow rates to each well, initially set flows to no more than ~ 3 gpm/well (unless operational data from the specific wells indicate more or less is appropriate).
10. Check each well.
11. Check all lines for drips/leaks, tighten/repair as required.
12. Increase (or decrease) flow to each well as injection capacity is determined.

5.2 Flow Meters

The flow meters consist of 2 parts: Burkert type S030 inline fitting (the paddlewheel unit) and a Burkert type 8035 flow totalizer/transmitter; operation manuals are attached. The flow transmitter attaches to the inline fitting with a ¼ twist and is secured with the small set-screw on the inline fitting. Check that the inline fitting has both O-rings (one on each end). Take care not to lose or pinch the O-rings, if O-rings are missing the unit cannot be used. Check that the internal paddle wheel is clean and flows freely when you blow on it (small pieces of leaves/grit/paper will make it stick). Use toothbrush to clean (gently) if required.

Zero the totalizer/flow meter at the start of an injection using the following steps:

1. Press the center button (down arrow) once, wait till it blinks and press it again, the meter should display 0.0 GA/M
2. Hold the two right buttons (down arrow and Enter key) for approximately 5 seconds, this brings the flow meter into a setup menu with the following options; Language (English), unit (gpm), K—factor (284.82), filter (2), total , Res (toggle to YES by hitting the down arrow in order to reset to zero)
3. Press the Enter key twice
4. Meter should then read 0,0 GA/M and then shortly switch to 0 GA totalized flow.

The K factor of 284.82 is for a 3/4-inch pipe, which is connected to the flowmeter, and units of GPM, any other pipe size or flow units require a different K-Factor (see attached operations manual, check all units carefully when changing the K-factor).

In standard operation, the flow meter reads the totalized flow. When adjusting the flow valves it is necessary to toggle the flow meters to the flow rate setting (gallons per minute);

1. Press the center button (down arrow) once, wait till it blinks and press it again and
2. the meter will display the flow rate in GA/M,
3. If the center button is held down the GA/M display will remain.
4. After the center button is released the display will revert back to the totalized flow in approximately 10 seconds.

5.3 Filter changes

The frequency of filter changes will depend on the consistency of the solution and it will vary. Loss of flow on the flow meters, changes in pump or flow meter sound, and pressures of greater than approximately 80 psi on the filter housing are signs that the filters may require changing.

The following steps describe the process of changing filters.

1. Identify flow through filter operation (parallel or serial flow).
2. Select filters to be placed in housings and verify size imprinted on outside of filter bag (typical 10 micron or 50 micron).
3. Turn off pump.
4. Close valve at outlet of Baker tank.
5. Slowly release pressure in filter housing by partially unscrewing the lid, allow all pressure to dissipate before removing lid.
6. Remove filter bag and cage to hold filter placing them into 5 gallon bucket.
7. Pour solution into open filter housing.
8. Remove filter and place in garbage bag.
9. Inspect the filters to determine which is plugging (based on slime layer on filter face), if both are plugging continue with same serial flow operation with 50 micron and 10 micron filters, if only the 2nd filter is plugging, switch to parallel flow with valving and use two 10 micron filter bags.
10. Replace with new filter and push the filter bag to bottom of cage.
11. Place cage and filter into the housing and push the top plastic ring to form a seal.
12. Open valve at outlet of Baker tank.
13. Allow the filters to refill and tighten the cap back on top of housing when the water level nears (within 3-4 inches) top of the housing.
14. If significant spills are present from the filter change, cleanup with shop vac.
15. Restart pump.
16. Check and adjust flow rates to each well.
17. Check each well.

Process and Finishing Steps

At the end of the event, record all the following data:

1. gallons/well for substrate
2. gallons/well for chase water

6.0 OTHER EQUIPMENT

The following equipment will be required, in adequate supply, for ERD injection:

1. pH probe
2. Brix meter
3. Pong filter bags, typically 10 and 50 micron
4. Trash pump for transfer
5. Injection pump and manifold/valves/flow-meters

CONTINGENCY PLAN AND EMERGENCY PROCEDURES CALIBRE STANDARD OPERATING PROCEDURES

1.0 POLICY

It is the policy of CALIBRE that any individual engaging in conducting field work on job sites will abide by the procedures outlined in this document. These emergency procedures are designed to meet or exceed applicable the Occupational Safety and Health Administration (OSHA) standards for safe work practices.

2.0 PURPOSE

The purpose of this contingency plan is to lessen the potential impact on the public health and the environment in the event of an emergency circumstance, including a fire, explosion, or unplanned release of dangerous waste or dangerous waste constituents to air, soil, surface water, or ground water. This contingency plan has been developed to eliminate or minimize potential impacts of such emergency circumstances, and the elements of this plan are to be implemented immediately in emergency circumstances.

3.0 RESPONSE ACTIONS

The key response actions to be taken in an emergency situation include the following:

- 1) In the event of a fire, worker will immediately notify the local fire department. If this person has been trained in the proper use of fire extinguishers, he or she may then attempt to extinguish the fire if this can be done safely, but only after first notifying the local fire department.
- 2) In the event of a small spill, the worker will immediately act to contain the spill using the on-site spill response materials. After the spill has been contained, the worker will arrange cleanup of the spill residuals and notify the client contact. For any larger spills, the worker will contact local emergency responders.
- 3) In the event of a fire, explosion, or other release that could threaten human health outside the facility or that has reached waters of the state, the worker must notify local emergency responders. Note the following:
 - The date, time, and type of incident;
 - The quantity and type of dangerous waste involved in the incident;
 - The extent of injuries, if any; and
 - The estimated quantity and disposition of recovered materials, if any.

All employees performing operation and maintenance activities at the site will understand proper waste handling and emergency procedures relative to their job responsibilities. As noted above, because of the limited number of employees working on the site, all employees will be responsible for reviewing and understanding the required procedures for management of process waste streams before they are allowed to work on site.

1) Description of Actions Which O&M Workers Must Take in Case of Emergency

Actions to be taken if any event occurs during operation of the project that is an emergency circumstance, including a fire, explosion, or unplanned release of waste or waste constituents to air, soil, surface water, or ground water will include:

- The equipment is to be shutdown immediately.
- If a fire exists, notify the fire department, use the on-site fire extinguisher.
- If a discharge exists, take immediate actions stop the discharge (shut off valve or other mechanism), call 911, use spill containment equipment to contain and cleanup any materials spilled.
- Notify client contacts and other project contacts (Attachment A).

2) Local Emergency Facilities

The Project Health and Safety Plan (present on site) describes the route to a hospital.

3) Emergency Equipment at the Facility

The emergency equipment located on site includes:

- fire extinguisher
- spill control equipment (storm drain cover, absorbent pads and bulk media, shop-vac and extension cord, brooms, storage drum, decontamination equipment).

This list will be updated as appropriate.

4) Copies of Contingency Plan

A copy of this contingency plan and all revisions to the plan will be maintained at the facility and submitted to all local emergency response teams that may be called upon to provide emergency services.

5) Amendments

The owner/operator will review and amend the contingency plan, if necessary, whenever any of the following occur:

- Applicable regulations or the facility permit are revised
- The plan fails in an emergency
- The facility changes (in its design, construction, operation, maintenance, or other circumstances) in a way that materially increases the potential for fires, explosions, or releases of dangerous waste or dangerous waste constituents, or in a way that changes the response necessary in an emergency
- The list of emergency coordinators changes
- The list of emergency equipment changes

DECONTAMINATION OF SAMPLING EQUIPMENT CALIBRE STANDARD OPERATING PROCEDURES

1.0 POLICY

It is the policy of CALIBRE that any individual engaging in field work requiring the decontamination of field equipment or instruments will abide by the procedures outlined in this document. These procedures are designed to meet or exceed applicable Occupational Safety and Health Administration (OSHA) standards for safe work practices.

2.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide the methods and procedures for decontamination of sampling or field equipment used in the collection of environmental samples and/or used for field activities at known or potentially contaminated sites.

3.0 SCOPE AND APPLICATION

This SOP should be used for decontaminating all disposable and non-disposable equipment used during field work. Items requiring decontamination may include personal protective equipment, sample equipment (shovels, trowels, pumps, tubing, depth to water probe, etc.) and heavy equipment (backhoes, direct-push probes, and drill rig augers). Upon completion of decontamination procedure, record that the decontamination activities have occurred in the field logbook and/or sample data record sheet.

4.0 EQUIPMENT

1. Potable water supply.
2. Liquinox or other specified cleaning agent.
3. Deionized (DI) water.
4. Buckets/tubs for wash and rinse.
5. Other decontamination liquids/solvents specified in site-specific plans.
6. Drums (55-gallon) or other containers for containerizing decontamination fluids.
7. Pressure washer and containment pad for heavy equipment.
8. Sample containers for sampling decontamination fluids (if required).

5.0 DECONTAMINATION PROCEDURES

5.1 Decontamination Procedures for Water Level Meters and the Water Quality Field Parameter Sensors

The electronic water level indicator probe/steel tape and the water-quality field parameter sensors will be decontaminated by the following procedures:

- The water level meter will be hand washed with phosphate free detergent and a scrubber, then thoroughly rinsed with distilled water.
- Water quality field parameter sensors and flow-through cell will be rinsed with distilled water between sampling locations. No other decontamination procedures are necessary or recommended for these probes since they are sensitive. After the sampling event, the flow cell and sensors must be cleaned and maintained per the manufacturer's requirements.

- Containerize, label, and sample (if required) all decontamination fluids for appropriate disposal.

5.2 Decontamination Procedure for Sampling Pumps

Upon completion of the groundwater sample collection the sampling pump must be properly decontaminated between monitoring wells. The pump and discharge line including support cable and electrical wires which were in contact with the groundwater in the well casing must be decontaminated by the following procedure:

- If a hydrophobic contaminant is present (such as separate phase, high levels of PCB's, etc.), an additional decontamination step, or steps, may be added. For example, an organic solvent, such as reagent-grade isopropanol alcohol may be added as a first spraying/bucket prior to the soapy water rinse/bucket. Acid washes are not typically used as they can corrode the sampling pumps.
- The outside of the pump, tubing, support cable and electrical wires must be pressured sprayed with soapy water, tap water and distilled water. Spray inside and outside of tubing and pump until water is flowing off of tubing after each rinse. Use bristle brush to help remove visible dirt and contaminants.
- Place the sampling pump in a bucket or in a short PVC casing (4-in. diameter) with one end capped. The pump placed in this device must be completely submerged in the water. A small amount of phosphate free detergent must be added to the potable water (tap water).
- Remove the pump from the bucket or 4-in. casing and scrub the outside of the pump housing and cable.
- Place pump and discharge line back in the 4-in. casing or bucket, start pump and re-circulate this soapy water for 2 minutes (wash).
- Re-direct discharge line to a 55-gallon drum; continue to add 5 gallons of potable water (tap water) or until soapy water is no longer visible.
- Turn pump off and place pump into a second bucket or 4-in. casing which contains tap water, continue to add 5-gallons of tap water (rinse).
- Turn pump off and place pump into a third bucket or 4-in. casing which contains distilled/deionized water, continue to add three to five gallons of distilled/deionized water (final rinse).
- Containerize, label, and sample (if required) all decontamination fluids for appropriate disposal.
- In the case of sampling equipment coming into contact with LNAPL or DNAPL the equipment must be decontaminated using solvent as a first cleaning step. Whenever possible it is important to inspect historical well data to prevent unexpected exposure to NAPLs.

5.3 Decontamination Procedures for General Field Sampling Equipment and PPE

Field sampling tools such as shovels, trowels, and PPE will be cleaned using the following procedures:

- Spray/rinse off excess dirt, mud, or other residue with potable water.
- Scrub sampling equipment and soiled PPE in potable water and Liquinox or other non-phosphate detergent.
- Rinse with potable water.
- Rinse reusable sampling equipment with deionized water, air dry, and store in aluminum foil.

- Rinse with methanol, hexane, isopropanol, nitric acid, or other cleaning agents if specified in QAPP or SAP.
- Dispose of all cleaned equipment/PPE appropriately.
- Containerize, label, and sample (if required) all decontamination fluids for appropriate disposal.

5.4 Decontamination Procedures for Heavy Equipment

Heavy equipment requiring decontamination may include drill rigs, drill augers, direct-push rods and samplers, backhoes, and other equipment that has contacted potentially contaminated media. The procedures include the following:

- Construct a lined containment pad for collection of all soil, residue, and decontamination fluids.
- Pressure wash equipment with potable water until clean.
- Rinse sampling equipment (such as direct-push split spoon or sampler) in DI water, air dry, and store in clean container (such as aluminum foil). Use other cleaning agents if specified in QAPP or SAP.
- Containerize all sediments/soils and decontamination fluids in 55-gallon drums. Separate media (soil, water) if possible and sample for appropriate disposal. Label all containers with contents, date, location, and contact information.
- Decontaminate containment pad or pad liner. Dispose of all non-reusable items appropriately after thoroughly decontaminated.
- Containerize, label, and sample (if required) all decontamination fluids for appropriate disposal.

6.0 HEALTH AND SAFETY CONSIDERATIONS

Follow all requirements of the project Health and Safety Plan (HASP). Ensure all field equipment has been decontaminated in accordance with the site-specific HASP and this SOP.

DIRECT-PUSH AND MONITORING WELL GROUNDWATER SAMPLING CALIBRE STANDARD OPERATING PROCEDURES

1.0 PURPOSE

This Standard Operating Procedure (SOP) provides instructions that are to be followed in collecting direct-push groundwater samples.

2.0 GROUNDWATER SAMPLING

The following sections describe sampling procedure to be used in the collection of direct-push groundwater samples from direct-push boreholes and monitoring wells.

2.1 Direct Push Groundwater Sampling

When the desired depth interval is reached, a push-rod is inserted into the center of the drill-string. Sections are added until the push-rod contacts the Direct-push point. After threading the rod on to the end cone and releasing it from the drill-string, the drill-string is retracted while holding the push-rod in place exposing the screen. The push-rod is withdrawn and new (unused) tubing with a foot valve on the end is lowered to a point where it is centered in the screen. A groundwater sample is extracted either with the use of a peristaltic pump or by applying a quick up and down motion to the tube until water comes out of the end of the tube. Teflon tubing or Teflon lined tubing should be used when sampling for organic chemicals near trace levels.

2.2 Monitoring Well Groundwater Sampling

Groundwater may be sampled in monitoring wells by use of Waterra pumps, peristaltic pumps, submersible pumps, or bailers. Regardless of the system employed, the point of collection (i.e. pump or foot valve) is placed at the mid-screen interval. Groundwater is withdrawn from the well until three well casing volumes have been removed and groundwater parameters (pH, temperature, conductivity, etc.) have stabilized. At that point, sample containers may be filled in accordance with project specific Field Sampling Plan procedures. Whenever feasible the methods described in the low-flow groundwater sampling SOP shall be used especially whenever trace amounts of chemicals are anticipated. For trace level VOC sampling, positive displacement sampling techniques should be used in lieu of peristaltic pumps or bailers.

2.3 Sample Handling

When the sample water appears, use the following the sequence of steps described below:

- (1) Label all bottles with required tags and labels. Fill out all information except the actual date and time. Sort bottles, one set per sampling location with additional sets as needed for QA/QC samples.
- (2) Note depth and bore location of the sample in the field logbook or sample data sheet.
- (3) At the time of individual sample collection, record date and time on all sample containers and in the field logbook. Cover all container labels with wide, transparent, waterproof tape to ensure label integrity.

- (4) Hold bottle so that water pours into it without the lip of the bottle touching the tube.
- (5) If the samples are being analyzed for volatile organic compounds (VOCs), collect the VOC fraction first. VOC vials should be filled to the top with a meniscus above the lip of the vial, leaving no airspace in the bottle when the lid is screwed on.
- (6) Fill the remaining bottles up to the shoulder of the bottle and seal with the cap.
- (7) Wipe off the outside of the bottle/vial and place it in a bubble baggie. Place the bagged bottle in a cooler, with ice if the sample plan calls for ice.
- (8) Decontaminate the sampling equipment for the next sample if sampling equipment is not dedicated or disposable.

2.4 Waste

Insure that all purge water and decontamination water, which may be contaminated, are handled and disposed of properly.

GROUNDWATER SAMPLING CALIBRE STANDARD OPERATING PROCEDURES

1.0 POLICY

It is the policy of CALIBRE that any individual engaging in collection of groundwater samples at job sites will abide by the procedures outlined in this document. These procedures are designed to meet or exceed guidelines set forth by the Environmental Protection Agency (EPA) for the collection of groundwater samples at Superfund or Resource Conservation and Recovery Act (RCRA) sites.

2.0 PURPOSE

This Standard Operating Procedure (SOP) provides instructions that are to be followed in collecting groundwater samples.

2.0 GROUNDWATER SAMPLING

The following sections describe sampling procedures to be used in the collection of groundwater samples from direct-push boreholes and monitoring wells. Whenever feasible the methods described in the low-flow groundwater sampling SOP shall be used especially whenever trace amounts of chemicals are anticipated.

2.1 Direct-Push Groundwater Sampling

When the desired depth interval is reached, a push-rod is inserted into the center of the drill-string. Sections are added until the push-rod contacts the direct-push point. After threading the rod on to the end cone and releasing it from the drill-string, the drill-string is retracted while holding the push-rod in place exposing the screen. The push-rod is withdrawn and fresh (unused) tygon tubing with a foot valve on the end is lowered to a point where it is centered in the screen. A groundwater sample is extracted either with the use of a peristaltic pump or by applying a quick up and down motion to the tube until water comes out of the end of the tube. Teflon tubing or Teflon lined tubing should be used when sampling for organic chemicals near trace levels.

2.2 Monitoring Well Groundwater Sampling

Groundwater may be sampled in monitoring wells by use of Waterra pumps, peristaltic pumps, submersible pumps, or bailers. Regardless of the system employed, the point of collection (i.e. pump or foot valve) is placed at the mid-screen interval. Groundwater is withdrawn from the well until three well casing volumes have been removed and groundwater parameters (pH, temperature, conductivity, etc.) have stabilized. At that point, sample containers may be filled in accordance with project specific Field Sampling Plan procedures. When sampling wells with trace levels of VOCs a positive displacement pump is preferred to the use of bailers or peristaltic pumps for groundwater extraction.

Prior to sampling historical data should be inspected to determine the likelihood of the presence of LNAPL or DNAPL. If NAPL is likely, use of a Waterra style pump may be preferred as the equipment can be readily decontaminated and disposed.

2.3 Sample Handling

When the sample water appears, use the sequence of steps described in the following list:

- 1) Label all bottles with required tags and labels. Fill out all information except the actual date and time. Sort bottles, one set per sampling location with additional sets as needed for QA/QC samples.
- 2) Note depth and bore location of the sample in the field logbook or sample data sheet.
- 3) At the time of individual sample collection, record date and time on all sample containers and in the field logbook. Cover all container labels with wide, transparent, waterproof tape to ensure label integrity.
- 4) Hold bottle so that water pours into it without the lip of the bottle touching the tube.
- 5) If the samples are being analyzed for volatile organic compounds (VOCs), collect the VOC fraction first. VOC vials should be filled to the top with a meniscus above the lip of the vial, leaving no airspace in the bottle when the lid is screwed on.
- 6) Fill the remaining bottles up to the shoulder of the bottle and seal with the cap.
- 7) Wipe off the outside of the bottle/vial and place it in a bubble baggie. Place the bagged bottle in a cooler, with ice if the sample plan calls for ice.
- 8) If sampling equipment is not dedicated or disposable, then decontaminate the sampling equipment for the next sample.

2.4 Waste

Insure that all purge water and decontamination water, which may be contaminated, are handled and disposed of properly.

LOW-FLOW GROUNDWATER SAMPLE COLLECTION CALIBRE STANDARD OPERATING PROCEDURES

1.0 POLICY

It is the policy of CALIBRE that any individual engaging in collection of low-flow groundwater samples at job sites will abide by the procedures outlined in this document. These procedures are designed to meet or exceed guidelines set forth by the Environmental Protection Agency (EPA) for the collection of low-flow groundwater samples at Superfund or Resource Conservation and Recovery Act (RCRA) sites.

2.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide a method that minimizes the impact the purging process has on the groundwater chemistry during sample collection and minimizes the volume of water that is being purged and disposed. The flow rate at which the pump will be operating will depend on both hydraulic conductivity of the aquifer and the drawdown, with the goal of minimizing the drawdown within the monitoring well. The flow rate from the pump during purging and sampling is targeted at a rate that will not compromise the integrity of the analyte that is being sampled. The operating flow of groundwater to the pump will depend on the hydraulic conductivity of the aquifer within the screen interval. In order to minimize the drawdown in the monitoring well, a low-flow rate must be utilized. Low-flow refers to the velocity with which water enters the pump intake from the surrounding formation in the immediate vicinity of the well screen. This SOP was developed to be consistent with guidelines from the Superfund/ RCRA Groundwater Forum and draws directly from a USEPA Groundwater Issue Paper, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers (Yeskis and Zavala, 2002).

3.0 SCOPE AND APPLICATION

This SOP should be used primarily at monitoring wells which have a screen or an open interval with a length of ten feet (typically) or less and can accept a sampling device that minimizes the disturbance to the aquifer or the water column in the well casing. The groundwater samples that are collected using this procedure are acceptable for the analyses of groundwater contaminants that may be found at typical groundwater contamination sites (CERCLA, RCRA and other sites). The analytes may be volatile organic compounds, semi-volatile organic compounds, pesticides, PCBs, metals and other inorganic compounds. The screened interval should be located within the contaminant plume(s) and the pump intake should be placed at or near the known source of the contamination within the screened interval. It is critical to place the pump intake in the same exact location or depth for each sampling event (indicating an obvious preference for permanently installed sampling devices where possible). If dedicated sampling pump is not possible, then the placement of the pump intake should be positioned with a pre-measured sampling pump hose. The pump intake should not be placed near the bottom of the screened interval to avoid disturbing any sediment that typically accumulates on the bottom of the well.

Water-quality indicator parameters (and water levels if feasible) must be measured during purging, prior to sample collection. Stabilization of the water quality parameters as well as monitoring water levels are prerequisites to sample collection. The water-quality indicator parameters that are recommended include: specific conductance, dissolved oxygen, oxidation-reduction potential, pH, and temperature. Turbidity may be useful but is not a required parameter. Also, when samples are

collected for metals, semi-volatile organic compounds, and pesticides, every effort must be made to reduce turbidity to 10 NTUs or less (not just the stabilization of turbidity) prior to the collection of the water sample. In addition to the measurement of the above parameters, depth to water should be measured (if feasible) during purging. However, recognizing that many groundwater monitoring wells are two-inch diameter, the pump assembly may not allow access for a depth to water probe.

Proper well construction, development, and maintenance are essential for any groundwater sampling procedure. Prior to conducting the field work, information on the construction of the well and well development should be obtained and that information factored into the site-specific sampling procedure. The attached Pre-Sampling Checklist is an example of the general type of information that is useful.

Stabilization of the water-quality indicator parameters is the criterion for sample collection. But if stabilization is not occurring and the procedure has been followed, then sample collection can take place once three (minimum) to six (maximum) casing volumes of groundwater have been removed from the well. The specific information on what took place during purging must be recorded in the field notebook or in the Well Sampling Data Sheet. This SOP is not to be used where non-aqueous phase liquids (immiscible fluids) are present in the monitoring well.

4.0 EQUIPMENT

- 1) Depth-to-water measuring device - An electronic water-level indicator (E-tape) or steel tape and chalk, with marked intervals of 0.01 foot. Interface probe for determination of non-aqueous phase liquids (NAPL) (if needed).
- 2) Steel tape and weight - Used for measuring total depth of well. Lead weight should not be used. If the wells are less than 75 feet deep, the E-tape may suffice for this total depth measurement, deeper wells may need steel tape and weight.
- 3) Sampling pump - Submersible or bladder pumps with adjustable rate controls are preferred. Pumps are to be constructed of inert materials, such as stainless steel and Teflon. Pump types that are acceptable include gear and helical driven, centrifugal (low-flow type) and air-activated piston.
- 4) Adjustable rate, peristaltic pump can be used when the depth to water is 20 feet or less.
- 5) Tubing - Teflon or Teflon lined polyethylene tubing is preferred when sampling for organic compounds. Polyethylene tubing can be used when sampling inorganics.
- 6) Power Source - If a combustion type (gasoline or diesel driven) generator is used, it must be placed downwind of the sampling area.
- 7) Flow measurement supplies - flow meter, graduated cylinder and a stop watch.
- 8) Multi-parameter meter with flow-through-cell. This can be one instrument or more contained in a flow-through cell. The water-quality indicator parameters which must be monitored are pH, oxidation-reduction potential (ORP), dissolved oxygen (DO), specific conductance, and temperature. The inlet of the flow cell must be located near the bottom of the flow cell and the outlet near the top. The size of the flow cell should be kept to a minimum and a closed cell is preferred. The flow cell must not contain any air or gas bubbles when monitoring for the water-quality indicator parameters.
- 9) Calibration fluids for all instruments. There needs to be sufficient volume of calibration solution for daily calibration throughout the sampling event.
- 10) Decontamination Supplies - Including a reliable and documented source of deionized (DI) or distilled water and any solvents (if used). Pressure sprayers, buckets, or decontamination tubs for pumps, brushes, and non-phosphate soap will also be needed.

- 11) Sample bottles, sample preservation supplies, sample tags or labels, and chain of custody forms.
- 12) Field Sampling and Quality Assurance Project Plan.
- 13) Well construction data, field and water quality data and water levels from the previous sampling event.
- 14) Well keys, tools to open well head monuments, and map of well locations.
- 15) Field notebook, Well Sampling Data Sheets/forms (attached), and calculator.
- 16) Filtration equipment (if needed for dissolved metals analyses). An in-line disposable filter is recommended.
- 17) Polyethylene sheeting which will be placed on ground around the well head.
- 18) Personal protective equipment specified in the site Health and Safety Plan, including any air monitoring equipment specified in the site Health and Safety Plan.
- 19) Tool box - All tools required for access to wells and for all site equipment used.
- 20) A 55-gallon drum or other appropriate container to contain the purged water.

Construction materials of the sampling equipment (bladders, pumps, tubing, and other equipment that comes in contact with the sample) should be limited to inert materials (such as stainless steel, Teflon, or other inert materials). This will reduce the chance of the sampling materials altering the groundwater where concentrations of the site contaminants are expected to be near the detection limits. The sample tubing diameter thickness should be maximized and the tubing length should be minimized so that the loss of contaminants into and through the tubing walls may be reduced and the rate of stabilization of groundwater parameters is maximized. The tendency of low level organics to sorb into and out of material makes the appropriate selection of sample tubing material critical for trace analyses.

5.0 CALIBRATION OF WATER QUALITY INSTRUMENTS

All water quality instruments to be used need to be calibrated (daily) following procedures in the instrument specific user manual.

6.0 DEPTH TO WATER AND PRE-SAMPLING ACTIVITIES (Non-dedicated and dedicated system)

- 1) Sampling events must begin at the monitoring well with the least contamination, generally up-gradient or farthest from the site or suspected source. Then proceed systematically to the monitoring wells with the most contaminated groundwater. Depth to water measurements should be collected in the same order.
- 2) Check and record the condition of the monitoring well for damage or evidence of tampering. If the ground surface indicates a potential for contamination (dirt, mud, debris or other), prepare the ground surface near the well to avoid contamination with clean plastic sheeting near/around the well to minimize the likelihood of contamination of sampling/purging equipment from surface soil contamination. Place monitoring, purging, and sampling equipment on the sheeting.
- 3) Unlock well head. Record location, time, date, and appropriate information in a field logbook or on the Well Sampling Data Sheet (See attached Well Sampling Data Sheet).
- 4) Remove well casing cap and observe any apparent pressure changes within the casing, if the cap is under vacuum or pressure allow the well time to equilibrate before measuring water levels .

- 5) As appropriate, monitor the headspace of the monitoring well at the rim of the casing for volatile organic compounds (VOC) with a photoionization detector (PID) or flame ionization detector (FID), and record in the logbook. If the existing monitoring well has a history of positive readings of the headspace, then the sampling must be conducted in accordance with the Health and Safety (H&S) Plan. This step may be skipped if prior data indicate that the specific well has not posed H&S issues in prior sampling.
- 6) Measure the depth to water (water level must be measured to nearest 0.01 feet) relative to a reference measuring point on the well casing with an E-tape or steel tape and record in logbook or Well Sampling Data Sheet. If no reference point is found, measure relative to the top of the inner casing, then mark that reference point and note that location in the field logbook. Record information on depth to groundwater in the field logbook or Well Sampling Data Sheet.
- 7) Measure the depth to water a second time to confirm initial measurement; measurement should agree within 0.01 feet or re-measure.
- 8) Check the available well information or field information for the total depth of the monitoring well. Use the information from the depth of water in step 6 and the total depth of the monitoring well to calculate the volume of the water in the monitoring well or the volume of one casing. Record information in field logbook or Well Sampling Data Sheet.

7.0 PURGING AND SAMPLING PROCEDURES

The following describes the purging and sampling procedures for the Low Flow method for the collection of groundwater samples. These procedures also describe steps for dedicated and non-dedicated systems.

7.1 Purging and Sampling Activities

Non-dedicated system - Place the pump and support equipment at the wellhead and slowly lower the pump and tubing down into the monitoring well until the location of the pump intake is set at a pre-determined location within the screen interval. The placement of the pump intake should be positioned with a calibrated sampling pump hose, sounded with a weighted-tape, or using a pre-measured discharge tubing. Refer to the available monitoring well information to determine the depth and length of the screen interval. Measure the depth of the pump intake while lowering the pump into location. Record pump location in field logbook or Well Sampling Data Sheet.

Dedicated system - Pump has already been installed, refer to the available monitoring well information and record the depth of the pump intake in the field logbook or Well Sampling Data Sheet.

Non-dedicated system and dedicated system

Measure the water level (water level must be measured to nearest 0.01 feet) and record information on the Well Sampling Data Sheet, leave water level indicator probe in the monitoring well (if sufficient space in casing).

Connect the discharge line from the pump to a flow-through cell. The discharge line from the flow-through cell must be directed to a container to contain the purge water during the purging and sampling of the monitoring well.

Start pumping the well at a low flow rate (0.2 to 0.5 liters per minute) and slowly increase the pumping rate. Check the water level if feasible: Note if the groundwater monitoring well is two-inch diameter, the pump assembly (pump, support cable, discharge hose, electrical supply, and pump booster stages in some cases) may fill the entire well casing access and a depth-to-water probe may not fit within the well casing. Field personnel need to exercise extreme care and good judgment when adding a probe to the tight space within a well. Equipment jammed or locked deep in a well casing may be lost/destroyed and future sampling access eliminated.

Maintain a steady flow rate while maintaining a drawdown of less than 0.33 feet (USEPA 2002). If drawdown is greater than 0.33 feet, lower the flow rate. The maximum drawdown of 0.33 feet is a goal to help guide with the flow rate adjustment. It should be noted that this goal may not be feasible under a number hydrogeologic conditions (relatively thin aquifers and/or low permeability soils). If this goal is not feasible, the sampling approach will require adjustment based on site-specific conditions and personal experience.

Measure the discharge rate of the pump with a graduated cylinder and a stop watch. Also, measure the water level, if feasible, and record both flow rate and water level on the Well Sampling Data Sheet. Continue purging, monitor and record water level and pump rate every three to five minutes during purging. Pumping rates should be kept at minimal flow to ensure minimal drawdown in the monitoring well.

During the purging, a minimum of one tubing volume (including the volume of water in the pump and flow cell) must be purged prior to recording the water-quality indicator parameters. Then monitor and record the water-quality indicator parameters every three to five minutes.

The water-quality indicator field parameters are pH, specific electrical conductance, ORP, dissolved oxygen, temperature, and turbidity. The ORP may not always be an appropriate stabilization parameter, and will depend on site-specific conditions. However, readings should be recorded because of its value as a double check for oxidizing conditions. The stabilization criterion is based on three successive readings of the water quality field parameters; the following are the criteria to be used :

Table 1. Parameter Stabilization Criteria Reference

pH	Conductance	ORP	DO	Temperature	Turbidity
+/- 0.1 pH unit	+/- 5% mS/cm	+/- 10 millivolts	+/- 0.3 mg/L	+/- 5% degrees Centigrade	+/- 10% NTUs (when greater than 10 NTUs)

Once the criteria have been successfully met indicating that the water quality indicator parameters have stabilized, then sample collection can take place. If a stabilized drawdown in the well can't be maintained at 0.33 feet and the water level is approaching the top of the screened interval, reduce the flow rate or turn the pump off (for 15 minutes) and allow for recovery to 90% of the height of the original water column. It should be noted whether or not the pump has a check valve. A check valve is required if the pump is shut off. Under no circumstances should the well be pumped dry. Begin pumping at a lower flow rate, if the water draws-down to the top of the screened interval again turn pump off and allow for recovery. If two tubing volumes (including the volume of water in the pump and flow cell) have been removed during purging then sampling can proceed the next time the pump is turned on. This information should be noted in the field notebook or Well Sampling Data Sheet with a recommendation for a different purging and sampling procedure.

Maintain the same pumping rate or reduce slightly for sampling (0.2 to 0.5 liter per minute) in order to minimize disturbance of the water column. Samples should be collected directly from the discharge port of the pump tubing prior to passing through the flow-through cell. Disconnect the pump's tubing from the flow-through-cell so that the samples are collected directly from the pump's discharge tubing.

For samples collected for dissolved gases or Volatile Organic Compound (VOC) analyses, the pump's tubing needs to be completely full of groundwater to prevent the groundwater from being aerated as the groundwater flows through the tubing. The sequence of the samples is immaterial unless filtered (dissolved) samples are collected and they must be collected last. All sample containers should be filled with minimal turbulence by allowing the groundwater to flow from the tubing gently down the inside of the container. When filling the VOC samples a meniscus must be formed over the mouth of the vial to eliminate the formation of air bubbles and head space prior to capping. In the event that the groundwater is turbid (greater than 10 NTUs), samples for metals should include a filtered metal (dissolved) sample.

If filtered metal sample is to be collected, then an in-line filter is fitted at the end of the discharge tubing and the sample is collected after the filter. The in-line filter must be pre-rinsed with groundwater following manufacturer's recommendations and if there are no recommendations for rinsing, a minimum of 0.5 to 1 liter of groundwater from the monitoring well must pass through the filter prior to sampling.

Non-dedicated system

Remove the pump from the monitoring well. Decontaminate the pump and tubing and dispose of non-dedicated tubing.

Dedicated system

Disconnect the tubing that extends from the discharge cap at the wellhead (or cap) and decontaminate and dispose of any non-dedicated discharge tubing.

Non-dedicated and dedicated system - Close and lock the well.

8.0 DECONTAMINATION PROCEDURES

Follow decontamination procedures from appropriate SOP. Sensors in the field water quality instruments are sensitive and rinsing with distilled water between sampling locations is the only decontamination recommended.

9.0 FIELD QUALITY CONTROL

Quality control (QC) samples must be collected to verify that sample collection and handling procedures were performed adequately and that sampling procedures have not compromised the quality of the groundwater samples. Follow all requirements of the site-specific Quality Assurance Project Plan (QAPP), typically to include some version of the following:

- Field duplicates (1 per 20 samples)
- Matrix spike/spike duplicate (extra volume at 1 per 20 samples or sample delivery group)

- Equipment blank (depends on sampling equipment use)
- Trip blank (for VOCs, 1 per sample cooler)
- Temperature blank (1 per sample cooler)
- Field Blank (as required in QAPP or 1 per sampling event)

10.0 HEALTH AND SAFETY CONSIDERATIONS

Follow all requirements of the project Health and Safety Plan. Ensure all field equipment has been decontaminated and stored appropriately.

11.0 POST-SAMPLING ACTIVITIES

Several activities need to be completed and documented once ground-water sampling has been completed. These activities include, but are not limited to:

- 1) If any equipment problems are noted, notify the CALIBRE Equipment Pool Manager before the item is returned to storage. Determine where the equipment item should be shipped.
- 2) Ensure that all field equipment has been decontaminated and returned to proper storage location. Once the individual field equipment item has been decontaminated, tag it with date of cleaning, site name, and name of individual responsible.
- 3) All field data should be compiled for site records.
- 4) All sample paperwork should be processed, including copies provided to the project manager, project files and any other project required sample handling and tracking facility.
- 5) All analytical data when processed by the analytical laboratory, should be verified against field sheets to ensure all planned data collection has been received from the laboratory.

12.0 REFERENCES

USEPA 2002. D. Yeskis and B. Zavala, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers. Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency. EPA 542.S-02-001. May 2002.

Puls, R.W. and M.J. Barcelona, 1996, Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures EPA/540/S-95/504. April, 1996.

PRE-SAMPLING CHECKLIST

Well Identification:	
Map of Site Included: Y or N	
Wells Clearly Identified w/ Roads: Y or N	
Well Construction Diagram Attached: Y or N	
Well Construction:	
Details of well monument/cap security; specific keys/tools to open: Any traffic or pedestrian control requirements (if needed):	
Diameter of Borehole:	Diameter of Casing:
Casing Material:	Screen Material:
Screen Length:	Total Depth:
Approximate Depth to Water:	and prior date:
Maximum Well Development Pumping Rate:	
Date of Last Well Development:	
Previous Sampling Information:	
Was the Well Sampled Previously: Y or N	
(If Sampled, Fill Out Table Below)	
Table of Previous Sampling Information	
Parameters Previously Sampled:	
Number of Times Sampled:	
Maximum Concentrations:	
Notes (include previous purge rates):	

Well Sampling Data Sheet

Date		Site Location	
Samplers		Well ID	
Casing Material		Constructed Depth	
Casing Diameter		Condition of Well	

Field Measurements:

Time		Depth Measured From:	
Depth to Water			Top of access port
			Mark on PVC casing
			Mark of protective casing
			Other

Purging Information:

Pump:		Dedicated		Non-dedicated	
Bailer:		PVC		Stainless Steel	Other:
Purge Start Time		Purge End Time			
Approximate Gallons Purged					

Water Monitoring Conditions:

Time							
pH							
Conductivity							
Turbidity							
D.O.							
Temperature							
ORP							
Purge Rate							
Gallons Purged							

Sampling Data:

Time		Sample ID	
pH		Duplicates	
Conductivity		QA/QC Volumes	
Turbidity			
D.O.			
Temperature			
ORP			

Sampling Device:

PVC Bailer		SS Bailer		Dedicated Pump		Teflon Bailer	
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Analyses to be Performed:

Volatile Organics		VOCs 8260B	SVOCs by 8270C		Sulfate 375.2	
Total Metals		RCRA 8 or	SVOCs by 8270C/SIM		RSK-175 (methane, ethane, ethene)	
Dissolved Metals		Priority Pollutants	Total Organic Carbon 415.1		Other	

Sampling Notes:

	Well Diameter Well Volume (Gal/ft) 1 inch 0.041 2 inch 0.163 4 inch 0.653 6 inch 1.469 Or: (total depth(ft) - DTW(ft)) x Well Dia ² x 0.0408 = 1 Well Volume
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PASSIVE DIFFUSION BAG SAMPLERS CALIBRE STANDARD OPERATING PROCEDURES

1.0 POLICY

It is the policy of CALIBRE that any individual engaging in groundwater sampling using passive diffusion bag samples will abide by the procedures outlined in this document. These procedures are designed to meet or exceed applicable regulatory procedures for sampling volatile organic compounds (VOCs) in groundwater using passive diffusion bag (PDB) samplers.

2.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide the methods and procedures for sampling groundwater for VOCs using PDB sampler.

3.0 SCOPE AND APPLICATION

Diffusion sampling is a relatively new technology designed to utilize passive sampling techniques without the need for well purging. Specifically, a diffusive membrane capsule is filled with deionized/distilled water, sealed, suspended in a well installation device, and lowered to a specified depth in a monitoring well. Over time (normally a minimum of 14 days), the volatile organic compounds (VOCs) in the groundwater diffuse across the membrane and reach equilibrium with the water inside the sampler. The sampler is subsequently removed from the well, and the water within the diffusion sampler is transferred to a sample container and submitted for laboratory analysis. Some benefits of using PDB samplers include reduced sampling costs and reduced generation of investigation-derived waste (IDW). The PDBs' ability to reflect dissolved VOC concentrations in the adjacent aquifer allows determination of stratification and vertical concentration gradients of VOC contaminants.

The PDB samplers were developed in the late 1990's and they become a widely accepted technique for determining concentrations of VOCs in groundwater monitoring wells. PDB samplers are commercially available and several brand names are available. The procedures for installing and retrieving PDB samplers may vary someone depending on the type of sampler that is being used. This SOP provides general methods and procedures for passive or polyethylene diffusion bag samplers; however, the specific procedures for each type of PDB you are using should be review to ensure the procedures you follow are in accordance with the manufacturer's procedure specific to the sampler being used.

PDB samplers are made of low density polyethylene (typically 4mils thick) film which serves as a semi-permeable membrane. The membrane is formed into the shape of a tube to create a sample chamber which is filled with de-ionized water and sealed. Various configurations are commercially available either pre-filled and sealed at both ends at the factory, or with a fill port and plug for filling at the factory, in the field, or at the user's lab. PDB samplers are typically 18 to 24 inches long and 1.25 to 1.75 inches in diameter to fit into a 2-inch diameter and larger monitoring wells. These dimensions provide 200 to 350 ml of sample for multiple VOA samples and duplicates. Other diameters and lengths are available to fit smaller diameter wells or to provide specific sample volumes. PDBs are available with an exterior polyethylene mesh that protects against abrasion.

Advantages of PDB samplers include:

- do not purge water
- only sample for VOC compounds
- effective in low yield wells
- allow for rapid installation and sample collection
- easy to use
- inexpensive to purchase and use
- samples discrete interval or can integrate sample over longer vertical interval
- multiple, stacked samplers provide vertical contaminant profile
- collect samples from discrete intervals in surface water bodies and tank

4.0 EQUIPMENT

1. PDB Sampling Forms.
2. Depth to water probe.
3. Rope or string to hold samplers.
4. Plastic sheeting.
5. Stainless steel weights.
6. Nylon zip-ties.
7. Scissors or device for opening samplers.
8. Decontamination supplies.
9. Drums (55-gallon) or other containers for containerizing excess groundwater or decontamination fluids.

5.0 SAMPLING PROCEDURES

New and clean nitrile gloves should be worn by any sampling personnel who will be in direct contact with any material that will, or that has the potential to, contact the groundwater.

5.1 Installing Passive Diffusion Bag Samplers

1. Measure the water elevation in the monitoring well in accordance with applicable site-specific SOPs. This will be used to determine how much of the well screen is in the saturated zone (i.e., saturated well-screen length). Note this depth on the Sampling Form.
2. Measure the total well depth and compare the measured depth with the depth to the reported bottom of the well screen on the PDB Sampling Form. This will provide information on whether sediment has accumulated in the bottom of the well or whether there is a blank section of pipe (sump) below the well screen.
3. Determine if the well screen is completely saturated. If not, determine the length of well screen that is saturated.
4. One sampler will be installed in each well unless specified differently by the project manager.
5. The PDB sampler should be placed in the center of the saturated screen interval and should be completely submerged throughout the equilibration period. If anticipated water elevation changes (based on historical data) may expose the top of the sampler to air, the diffusion sampler should be placed deeper.

6. If assembly work is conducted on the ground, prepare the ground surface near the well for assembly of the diffusion sampler string, place clean plastic sheeting near the well and sample string construction will be performed on the plastic sheeting. If assembly is completed in vehicle, verify work area is clean.
7. Attach the stainless steel weight to the sampling assembly/line (a weight and weight hanger slides over the bag and the top of the bag is snapped on the suspension line, which is 60# braided fishing line, or other assembly procedure depending on the PDB bag and model).
8. Lower the PDB and assembly into the well to the target interval (typically to the bottom of the well then raised back up 5 ft, or other procedure/interval defined in the work plan).
9. Use a total of two zip-ties per PDB sampler. Finally, place a knot or a zip-tie at the location on the rope that corresponds to the top of the well casing.
10. Record in the field logbook and the PDB Sampling Form the depth at which each sampler is to be installed.
11. Attach the top and bottom of the diffusion sampler to the rope using the zipties that were inserted into the rope in Step 9 above. If no obvious hook exists on the sampler to which to attach the sampler to the rope using the zip-tie, attach the sampler to the rope by weaving the zip-tie through the mesh tubing of the diffusion sampler. The zip-ties should be threaded through the mesh tubing in a way that prevents the polyethylene diffusion bag from sliding out of the mesh and in a way that prevents slack from developing in the rope between the bottom and top of the sampler.
12. Samples that will be collected in duplicate for quality control (QC) purposes may require additional sample volume to fill the required sample containers. In these instances, utilize either oversized, longer samplers (for 2-inch diameter wells) or attach two regular samplers to the same depth interval on the rope (for wells with a casing diameter larger than 2-inches). Check the volume of the sampler and laboratory volume requirements to determine if an additional sampler is required.
13. Using decontaminated scissors (see Decontamination SOP), trim the excess from the zip-ties before placing the sampling string down the well.
14. Gently lower the diffusion sampling string into the well (weight first) until the weight rests on the bottom and the upper knot or zip-tie (indicating the top of the well casing) is even with the top of the well casing. The diffusion sampler should now be positioned at the correct depths.
15. Secure the rope or string at the wellhead in this position. A suggested method is to attach the rope to a hook (if one exists) on the inside of the well cap or the cap can be fitted over the rope to hold the rope at the desired depth.
16. If the well cap cannot be installed over the rope, install a temporary cover over the well casing to prevent debris from entering the well.
17. Close and lock the well protective covering.

18. Leave the sampling string in place for at least 14 days (or as specified in the Work Plans).

5.2 Diffusion Sampler Recovery and Sample Collection

This section describes the procedures for retrieving PDB samplers from groundwater monitoring wells. Following the equilibration period, the diffusion sampling string will be retrieved and samples will be collected for field screening and laboratory analysis using the following procedures.

1. Measure the water level in the monitoring well in accordance with applicable site-specific SOPs. Note this depth on the sample collection form and verify that the top of the PDB sampler is completely submerged below the water level.

2. Gently but quickly reel up (or pull) the sampler on the string.

3. Cut the cable ties and remove the diffusion sampler from the rope. Examine the surface of the diffusion sampler for evidence of algae or a film that could affect the performance of the diffusion membrane. Note any observations in the sampling field book and on the PDB Sampling Form.

5. Cut open the diffusion sampler using a properly decontaminated pair of scissors and gently pour the water into three (3) 40-mL VOA vials (or as specified in the Work Plans). As an alternative to using scissors, a fill kit may be provided by the PDB supplier for transferring water from the PDB to the sample container. Regardless of the method of transference, the water should be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample. **WATER NEEDS TO BE TRANSFERRED FROM THE DIFFUSION SAMPLERS TO THE VOA VIALS AS QUICKLY AS POSSIBLE TO MINIMIZE CONTAMINANT VOLATILIZATION.**

6. Once filled to the brim, sample bottles will be sealed in a manner such that there is no headspace (i.e., no air bubbles).

7. Sample bottle preservation, labeling, and shipment will be performed according to the procedures detailed in the Sample Packaging and Shipment SOP.

8. Excess water from the diffusion samplers will be collected in sealable plastic buckets or steel drums for containment until it is disposed of. All investigation derived waste (IDW), including excess sample water, spent diffusion samplers, disposable sampling equipment, and personal protective equipment will be managed according to the criteria specified in the IDW plan specified in the site Work Plan.

6.0 HEALTH AND SAFETY CONSIDERATIONS

Follow all requirements of the project Health and Safety Plan (HASP). Ensure all field equipment has been decontaminated in accordance with the site-specific HASP and the decontamination SOP.

7.0 Selected References

ITRC, 2004. Technical and Regulatory Guidance for Using Polyethylene Diffusion Bag Samplers to Monitor Volatile Organic Compounds in Groundwater.

Parsons 2004. Final Comprehensive Results Report for the Passive Diffusion Bag Sampler Demonstration.

ITRC— Technical Overview of Passive Sampler Technologies March 2006

Vroblesky, D. A. 2001. User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compounds Concentrations in Wells, Part 1 and 2.

US Geological Survey Water Resources Investigation Reports 01-4060 and 01-4061.
ITRC, Diffusion Sampler Information Center (DSIC),
<http://diffusionsampler.itrcweb.org/common/default.asp>

NJDEP, August 2005, Field Sampling Procedures Manual, Chapters 5 and 6.
<http://www.state.nj.us/dep/srp/guidance/fspm/>

8.0 Contact Information

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PHOTOIONIZATION DETECTOR (PID) CALIBRATION AND USE CALIBRE STANDARD OPERATING PROCEDURES

1.0 POLICY

It is the policy of CALIBRE that any individual engaging in the use of a photoionization detector (PID) on jobsites will abide by the procedures outlined in this document. These procedures are designed to meet or exceed applicable OSHA standards for safe work practices.

2.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to describe the procedures for using a photoionization detector (PID).

3.0 SCOPE AND APPLICATION

The PID is a portable, nonspecific, vapor/gas detector employing the principle of photoionization to detect a variety of chemical compounds, both organic and inorganic, in air. This procedure is applicable to the PIDs used for air monitoring. These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent on site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and reported.

4.0 METHOD SUMMARY

The PID is a useful general survey instrument at hazardous waste sites. A PID is capable of detecting and measuring real-time concentrations of many organic and inorganic vapors in air. A PID is similar to a flame ionization detector (FID) in application; however, the PID has somewhat broader capabilities in that it can detect certain inorganic vapors. Conversely, the PID is unable to respond to certain low molecular weight hydrocarbons, such as methane and ethane that are readily detected by FID instruments.

The PID employs the principle of photoionization. The analyzer will respond to most vapors that have an ionization potential less than or equal to that supplied by the ionization source, which is an ultraviolet (UV) lamp. Photoionization occurs when an atom or molecule absorbs a photon of sufficient energy to release an electron and form a positive ion. This will occur when the ionization potential of the molecule in electron volts (eV) is less than the energy of the photon. The sensor is housed in a probe and consists of a sealed ultraviolet light source that emits photons with an energy level high enough to ionize many trace organics, but not enough to ionize the major components of air (e.g., nitrogen, oxygen, carbon dioxide). The ionization chamber exposed to the light source contains a pair of electrodes, one a bias electrode, and the second the collector electrode. When a positive potential is applied to the bias electrode, an electro-magnetic field is created in the chamber. Ions formed by the adsorption of photons are driven to the collector electrode. The current produced is then measured and the corresponding concentration displayed on a meter, directly, in units above background. Several probes are available for the PID, each having a different eV lamp and a different ionization potential. The selection of the appropriate probe is essential in obtaining useful field results. Though it can be calibrated to a particular compound, the instrument cannot distinguish between detectable compounds in a mixture of gases and, therefore, indicates an integrated response to the mixture.

Three probes, each containing a different UV light source, are available for many PIDs. Energies are 9.5, 10.2, and 11.7 eV. All three detect many aromatic and large molecular hydrocarbons. The 10.2 eV and 11.7 eV probes, in addition, detect some smaller organic molecules and some halogenated hydrocarbons. The 10.2 eV probe is the most useful for environmental response work, as it is more durable than the 11.7 eV probe and detects more compounds than the 9.5 eV probe.

Gases with ionization potentials near to or less than that of the lamp will be ionized. These gases will thus be detected and measured by the analyzer. Gases with ionization potentials higher than that of the lamp will not be detected. Ionization potentials for various atoms, molecules, and compounds are given in standard references (see attached in Appendix A).

5.0 INTERFERENCES AND POTENTIAL PROBLEMS

5.1 PID Instrument Limitations

- 1) The PID is a nonspecific total vapor detector. It cannot be used to identify unknown substances; it can only roughly quantify them.
- 2) The PID must be calibrated to a specific compound (or including a conversion factor for equivalent response such as isobutylene)
- 3) The PID does not respond to certain low molecular weight hydrocarbons, such as methane and ethane. In addition, the PID does not detect a compound if the probe has a lower energy than the compound's ionization potential.
- 4) Certain toxic gases and vapors, such as carbon tetrachloride and hydrogen cyanide, have high ionization potentials and cannot be detected with a PID.
- 5) Certain models of PID instruments are not designed for use in potentially flammable or combustible atmospheres.
- 6) The lamp window must be periodically cleaned to ensure ionization of the new compounds by the probe (i.e., new air contaminants).
- 7) The PID measures concentrations are not linear over this entire range. For example, if calibrated to benzene, the response is linear from about 0-600 units above background. This means the PID reads a true concentration of benzene only between 0 and 600.
- 8) This instrument is not to be exposed to precipitation (rain). The units are not designed for this service. Significant humidity may impair the accuracy of the PID.
- 9) Do not use this instrument for head space analysis where liquids can inadvertently be drawn into the probe.

5.2 Regulatory Limitations

Transport of calibration gas cylinders by passenger and cargo aircraft must comply with International Air Transport Association (IATA) Dangerous Goods Regulations or the U.S. Code of Federal Regulations, 49 CFR Parts 100-177. A typical calibration gas included with a PID is isobutylene. It is classified as a non-flammable gas, UN #1556 and the proper shipping name is Compressed Gas. It must be shipped by cargo aircraft only.

6.0 EQUIPMENT/APPARATUS

The following equipment is required for PID operation:

- 1) PID
- 2) Operating manual
- 3) Probes: 9.5 eV, 10.2 eV, or 11.7 eV
- 4) Battery charger for PID
- 5) Spare batteries
- 6) Jeweler's screwdriver for adjustments
- 7) Tygon tubing
- 8) NBS traceable calibration gas (isobutylene) or other gas when calibrating to specific compound
- 9) "T" valve for calibration
- 10) Field Data Sheets/Site Logbook
- 11) Intake assembly extension
- 12) Strap for carrying PID
- 13) Teflon tubing for downhole measurements
- 14) Plastic bags for protecting the PID from moisture and dirt
- 15) Mild soap solution for cleaning unit surfaces, Methanol for cleaning ionization chamber (GC grade), and Light source cleaning compound (if applicable)

Note: Battery charge status - This instrument may be kept on continuous charge without battery damage.

The PID is calibrated in accordance with the operations manual using isobutylene as the calibration standard. The operations manual may also be referred to for alternate calibration to a specific compound.

7.0 PROCEDURES

7.1 Preparation

Check out and ensure the proper operation of the PID, as appropriate, using the equipment checklist provided in Sections 6.0 and the steps listed below.

7.2 Start-Up Procedures

- 1) Allow the temperature of the unit to equilibrate to its surrounding. This should take about five minutes.
- 2) Attach the probe to the unit.
- 3) Turn the instrument to ON.
- 4) Zero the instrument per the operations manual
- 5) Check the SPAN with calibration gas
- 6) Set the PID to the desired range (i.e., 0-20, 0-200, 0-2000, if applicable based on unit).
- 7) Listen for the vacuum pump operation to verify function.
- 8) Check instrument with a point calibration gas, and other source, such as a magic marker, prior to survey to verify instrument function.
- 9) Routinely during the day, verify the unit calibration and recalibrate the instrument if necessary

7.3 Field Calibration and Operation

7.3.1 Field Calibration

Follow the start-up procedure in Section 7.2. Set the FUNCTION switch to the range setting which includes the concentration of the calibration gas. Calibrate as follows:

1. Attach a regulator to a disposable cylinder of calibration gas. Connect the regulator to the probe of the PID with a piece of clean tygon tubing. Open the valve on the regulator.
2. After 15 seconds, the meter reading should equal the response value as indicated on the calibration gas cylinder used. If the reading is within $\pm 15\%$ of the response value, then the instrument can be field calibrated to the response value using the external SPAN ADJUSTMENT control. The SPAN ADJUSTMENT control should be adjusted to a lower setting until the correct reading has been obtained. The lower the number on the SPAN ADJUSTMENT control, the greater the instrument sensitivity. If the SPAN ADJUSTMENT control has to be adjusted below a setting of 4.00, the unit should be red-tagged and returned for repairs.
3. If the meter reading is greater than $\pm 15\%$ of the response value of the calibration gas used, then the instrument should be red-tagged and returned for repair.
4. Record the calibration of instrument in the instrument calibration log and field logbook including: instrument model and ID number, date, time, initial and final span settings, and concentration and type of calibration gas.
5. In some field applications, with the exception of the probe's inlet and exhaust, the PID should be wrapped in clear plastic to prevent it from becoming contaminated and to prevent water from getting inside in the event of precipitation.

7.3.2 Operation

1. All readings are to be recorded in the site logbook. Readings should be recorded as "units above background," not ppm.
2. As with any field instrument, accurate results depend on the operator being completely familiar with the operator's manual. The instructions in the operating manual should be followed explicitly in order to obtain accurate results.
3. Position the probe assembly close to the area to be monitored because the low sampling rate allows for only very localized readings. Under no circumstances should the probe tip assembly be immersed in fluid.
4. While taking care to prevent the PID from being exposed to excessive moisture, dirt, or contamination, monitor the work activity as specified in the site Health and Safety Plan. The PID survey should be conducted at a slow to moderate rate of speed and the intake assembly (the probe) slowly swept from side to side. There is a three to five second delay in the read-out depending upon the instruments sensitivity to the contaminant.
5. During drilling activities, PID monitoring is to be performed at regular intervals downhole and in the breathing zone. When opening monitoring wells readings should be taken at the wellhead and in the breathing zone. Always follow the air monitoring requirements specified in the site-specific Health and Safety Plan.

7.4 Post Operation

1. Turn FUNCTION Switch to OFF.

2. Return the PID to a secure area and check the calibration (Section 7.3.1.) before charging. Connect the instrument to charger and plug in the charger. The probe must be connected to the readout unit to charge the HNU type PID.
3. Complete logbook entries, verifying the accuracy of entries, and sign/initial all pages.

8.0 QUALITY ASSURANCE/QUALITY CONTROL

There are no specific quality assurance activities which apply to the implementation of these procedures. However, the following general QA procedures apply:

1. All data must be documented on field data sheets or within site logbooks.
2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation, and they must be documented.

9.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA, and site-specific Health and Safety practices.



Correction Factors, Ionization Energies*, And Calibration Characteristics

Correction Factors and Ionization Energies

RAE Systems PIDs can be used for the detection of a wide variety of gases that exhibit different responses. In general, any compound with ionization energy (IE) lower than that of the lamp photons can be measured.* The best way to calibrate a PID to different compounds is to use a standard of the gas of interest. However, correction factors have been determined that enable the user to quantify a large number of chemicals using only a single calibration gas, typically isobutylene. In our PIDs, correction factors can be used in one of three ways:

- 1) Calibrate the monitor with isobutylene in the usual fashion to read in isobutylene equivalents. Manually multiply the reading by the correction factor (CF) to obtain the concentration of the gas being measured.
- 2) Calibrate the unit with isobutylene in the usual fashion to read in isobutylene equivalents. Call up the correction factor from the instrument memory or download it from a personal computer and then call it up. The monitor will then read directly in units of the gas of interest.
- 3) Calibrate the unit with isobutylene, but input an equivalent, "corrected" span gas concentration when prompted for this value. The unit will then read directly in units of the gas of interest.

* The term "ionization energy" is more scientifically correct and replaces the old term "ionization potential." High-boiling ("heavy") compounds may not vaporize enough to give a response even when their ionization energies are below the lamp photon energy. Some inorganic compounds like H_2O_2 and NO_2 give weak response even when their ionization energies are well below the lamp photon energy.

Example 1:

With the unit calibrated to read isobutylene equivalents, the reading is 10 ppm with a 10.6 eV lamp. The gas being measured is butyl acetate, which has a correction factor of 2.6. Multiplying 10 by 2.6 gives an adjusted butyl acetate value of 26 ppm. Similarly, if the gas being measured were trichloroethylene (CF = 0.54), the adjusted value with a 10 ppm reading would be 5.4 ppm.

Example 2:

With the unit calibrated to read isobutylene equivalents, the reading is 100 ppm with a 10.6 eV lamp. The gas measured is m-xylene (CF = 0.43). After downloading this factor, the unit should read about 43 ppm when exposed to the same gas, and thus read directly in m-xylene values.

Example 3:

The desired gas to measure is ethylene dichloride (EDC). The CF is 0.6 with an 11.7 eV lamp. During calibration with 100 ppm isobutylene, insert 0.6 times 100, or 60 at the prompt for the calibration gas concentration. The unit then reads directly in EDC values.

Conversion to mg/m^3

To convert from ppm to mg/m^3 , use the following formula:

$$\text{Conc. (mg/m}^3\text{)} = \frac{[\text{Conc. (ppmv)} \times \text{mol. wt. (g/mole)}]}{\text{molar gas volume (L)}}$$

For air at 25 °C (77 °F), the molar gas volume is 24.4 L/mole and the formula reduces to:

$$\text{Conc. (mg/m}^3\text{)} = \text{Conc. (ppmv)} \times \text{mol. wt. (g/mole)} \times 0.041$$

For example, if the instrument is calibrated with a gas standard in ppmv, such as 100 ppm isobutylene, and the user wants the display to read in mg/m^3 of hexane, whose m.w. is 86 and CF is 4.3, the overall correction factor would be $4.3 \times 86 \times 0.041$ equals 15.2.

Correction Factors for Mixtures

The correction factor for a mixture is calculated from the sum of the mole fractions X_i of each component divided by their respective correction factors CF_i :

$$CF_{\text{mix}} = 1 / (X_1/CF_1 + X_2/CF_2 + X_3/CF_3 + \dots X_i/CF_i)$$

Thus, for example, a vapor phase mixture of 5% benzene and 95% n-hexane would have a CF_{mix} of $CF_{\text{mix}} = 1 / (0.05/0.53 + 0.95/4.3) = 3.2$. A reading of 100 would then correspond to 320 ppm of the total mixture, comprised of 16 ppm benzene and 304 ppm hexane.



For a spreadsheet to compute the correction factor and TLV of a mixture see the appendix at the end of the CF table.

TLVs and Alarm Limits for Mixtures

The correction factor for mixtures can be used to set alarm limits for mixtures. To do this one first needs to calculate the exposure limit for the mixture. The Threshold Limit Value (TLV) often defines exposure limits. The TLV for the mixture is calculated in a manner similar to the CF calculation:

$$\text{TLV mix} = 1 / (X_1/\text{TLV}_1 + X_2/\text{TLV}_2 + X_3/\text{TLV}_3 + \dots X_i/\text{TLV}_i)$$

In the above example, the 8-h TLV for benzene is 0.5 ppm and for n-hexane 50 ppm. Therefore the TLV of the mixture is $\text{TLV}_{\text{mix}} = 1 / (0.05/0.5 + 0.95/50) = 8.4$ ppm, corresponding to 8.0 ppm hexane and 0.4 ppm benzene. For an instrument calibrated on isobutylene, the reading corresponding to the TLV is:

$$\text{Alarm Reading} = \text{TLV}_{\text{mix}} / \text{CF}_{\text{mix}} = 8.4 / 3.2 = 2.6 \text{ ppm}$$

A common practice is to set the lower alarm limit to half the TLV, and the higher limit to the TLV. Thus, one would set the alarms to 1.3 and 2.6 ppm, respectively.

Calibration Characteristics

a) Flow Configuration. PID response is essentially independent of gas flow rate as long as it is sufficient to satisfy the pump demand. Four main flow configurations are used for calibrating a PID:

- 1) Pressurized gas cylinder (Fixed-flow regulator):** The flow rate of the regulator should match the flow demand of the instrument pump or be slightly higher.
- 2) Pressurized gas cylinder (Demand-flow regulator):** A demand-flow regulator better matches pump speed differences, but results in a slight vacuum during calibration and thus slightly high readings.
- 3) Collapsible gas bag:** The instrument will draw the calibration gas from the bag at its normal flow rate, as long as the bag valve is large enough. The bag should be filled with enough gas to allow at least one minute of flow (~ 0.6 L for a MiniRAE, ~0.3 L for MultiRAE).

4) T (or open tube) method: The T method uses a T-junction with gas flow higher than the pump draw. The gas supply is connected to one end of the T, the instrument inlet is connected to a second end of the T, and excess gas flow escapes through the third, open end of the T. To prevent ambient air mixing, a long tube should be connected to the open end, or a high excess rate should be used. Alternatively, the instrument probe can be inserted into an open tube slightly wider than the probe. Excess gas flows out around the probe.

The first two cylinder methods are the most efficient in terms of gas usage, while the bag and T methods give slightly more accurate results because they match the pump flow better.

- b) Pressure.** Pressures deviating from atmospheric pressure affect the readings by altering gas concentration and pump characteristics. It is best to calibrate with the instrument and calibration gas at the same pressure as each other and the sample gas. (Note that the cylinder pressure is not relevant because the regulator reduces the pressure to ambient.) If the instrument is calibrated at atmospheric pressure in one of the flow configurations described above, then 1) pressures slightly above ambient are acceptable but high pressures can damage the pump and 2) samples under vacuum may give low readings if air leaks into the sample train.
- c) Temperature.** Because temperature effects gas density and concentration, the temperature of the calibration gas and instrument should be as close as possible to the ambient temperature where the unit will be used. We recommend that the temperature of the calibration gas be within the instrument's temperature specification (typically 14° to 113° F or -10° to 45° C). Also, during actual measurements, the instrument should be kept at the same or higher temperature than the sample temperature to avoid condensation in the unit.
- d) Matrix.** The matrix gas of the calibration compound and VOC sample is significant. Some common matrix components, such as methane and water vapor can affect the VOC signal. PIDs are

most commonly used for monitoring VOCs in air, in which case the preferred calibration gas matrix is air. For a MiniRAE, methane, methanol, and water vapor reduce the response by about 20% when their concentration is 15,000 ppm and by about 40% at 30,000 ppm. Despite earlier reports of oxygen effects, RAE PID responses with 10.6 eV lamps are independent of oxygen concentration, and calibration gases in a pure nitrogen matrix can be used. H₂ and CO₂ up to 5 volume % also have no effect.

- e) Concentration.** Although RAE Systems PIDs have electronically linearized output, it is best to calibrate in a concentration range close to the actual measurement range. For example, 100 ppm standard gas for anticipated vapors of 0 to 250 ppm, and 500 ppm standard for expected concentrations of 250 to 1000 ppm. The correction factors in this table were typically measured at 50 to 100 ppm and apply from the ppb range up to about 1000 ppm. Above 1000 ppm the CF may vary and it is best to calibrate with the gas of interest near the concentration of interest.
- f) Filters.** Filters affect flow and pressure conditions and therefore all filters to be used during sampling should also be in place during calibration. Using a water trap (hydrophobic filter) greatly reduces the chances of drawing water aerosols or dirt particles into the instrument. Regular filter replacements are recommended because dirty filters can adsorb VOCs and cause slower response time and shifts in calibration.
- g) Instrument Design.** High-boiling ("heavy") or very reactive compounds can be lost by reaction or adsorption onto materials in the gas sample train, such as filters, pumps and other sensors. Multi-gas meters, including EntryRAE, MultiRAE and AreaRAE have the pump and other sensors upstream of the PID and are prone to these losses. Compounds possibly affected by such losses are shown in green in the table, and may give slow response, or in extreme cases, no response at all. In many cases the multi-gas meters can still give a rough indication of the relative concentration, without giving an accurate,

quantitative reading. The ppbRAE and MiniRAE series instruments have inert sample trains and therefore do not exhibit significant loss; nevertheless, response may be slow for the very heavy compounds and additional sampling time up to a minute or more should be allowed to get a stable reading.

Table Abbreviations:

CF = Correction Factor (multiply by reading to get corrected value for the compound when calibrated to isobutylene)

NR = No Response

IE = Ionization Energy (values in parentheses are not well established)

C = Confirmed Value indicated by "+" in this column; all others are preliminary or estimated values and are subject to change

ne = Not Established ACGIH 8-hr. TWA

C## = Ceiling value, given where 8-hr. TWA is not available

Disclaimer:

Actual readings may vary with age and cleanliness of lamp, relative humidity, and other factors. For accurate work, the instrument should be calibrated regularly under the operating conditions used. The factors in this table were measured in dry air at room temperature, typically at 50-100 ppm. CF values may vary above about 1000 ppm.

Updates:

The values in this table are subject to change as more or better data become available. Watch for updates of this table on the Internet at

<http://www.raesystems.com>

IE data are taken from the CRC Handbook of Chemistry and Physics, 73rd Edition, D.R. Lide (Ed.), CRC Press (1993) and NIST Standard Ref. Database 19A, NIST Positive Ion Energetics, Vers. 2.0, Lias, et.al., U.S. Dept. Commerce (1993). Exposure limits (8-h TWA and Ceiling Values) are from the 2005 ACGIH Guide to Occupational Exposure Values, ACGIH, Cincinnati, OH 2005. Equations for exposure limits for mixtures of chemicals were taken from the 1997 TLVs and BEIs handbook published by the ACGIH (1997).



Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Acetaldehyde		75-07-0	C ₂ H ₄ O	NR	+	6	+	3.3	+	10.23	C25
Acetic acid	Ethanoic Acid	64-19-7	C ₂ H ₄ O ₂	NR	+	22	+	2.6	+	10.66	10
Acetic anhydride	Ethanoic Acid Anhydride	108-24-7	C ₄ H ₆ O ₃	NR	+	6.1	+	2.0	+	10.14	5
Acetone	2-Propanone	67-64-1	C ₃ H ₆ O	1.2	+	1.1	+	1.4	+	9.71	500
Acetone cyanohydrin	2-Hydroxyisobutyronitrile	75-86-5	C ₄ H ₇ NO					4	+	11.1	C5
Acetonitrile	Methyl cyanide, Cyanomethane	75-05-8	C ₂ H ₃ N					100		12.19	40
Acetylene	Ethyne	74-86-2	C ₂ H ₂					2.1	+	11.40	ne
Acrolein	Propenal	107-02-8	C ₃ H ₄ O	42	+	3.9	+	1.4	+	10.10	0.1
Acrylic acid	Propenoic Acid	79-10-7	C ₃ H ₄ O ₂			12	+	2.0	+	10.60	2
Acrylonitrile	Propenenitrile	107-13-1	C ₃ H ₃ N			NR	+	1.2	+	10.91	2
Allyl alcohol		107-18-6	C ₃ H ₆ O	4.5	+	2.4	+	1.6	+	9.67	2
Allyl chloride	3-Chloropropene	107-05-1	C ₃ H ₅ Cl			4.3		0.7		9.9	1
Ammonia		7664-41-7	H ₃ N	NR	+	9.7	+	5.7	+	10.16	25
Amyl acetate	mix of n-Pentyl acetate & 2-Methylbutyl acetate	628-63-7	C ₇ H ₁₄ O ₂	11	+	2.3	+	0.95	+	<9.9	100
Amyl alcohol	1-Pentanol	75-85-4	C ₅ H ₁₂ O			5		1.6		10.00	ne
Aniline	Aminobenzene	62-53-3	C ₇ H ₇ N	0.50	+	0.48	+	0.47	+	7.72	2
Anisole	Methoxybenzene	100-66-3	C ₇ H ₈ O	0.89	+	0.58	+	0.56	+	8.21	ne
Arsine	Arsenic trihydride	7784-42-1	AsH ₃			1.9	+			9.89	0.05
Benzaldehyde		100-52-7	C ₇ H ₆ O					1		9.49	ne
Benzenamine, N-methyl-	N-Methylphenylamine	100-61-8	C ₇ H ₉ N			0.7				7.53	
Benzene		71-43-2	C ₆ H ₆	0.55	+	0.53	+	0.6	+	9.25	0.5
Benzonitrile	Cyanobenzene	100-47-0	C ₇ H ₅ N			1.6				9.62	ne
Benzyl alcohol	α-Hydroxytoluene, Hydroxymethylbenzene, Benzenemethanol	100-51-6	C ₇ H ₈ O	1.4	+	1.1	+	0.9	+	8.26	ne
Benzyl chloride	α-Chlorotoluene, Chloromethylbenzene	100-44-7	C ₇ H ₇ Cl	0.7	+	0.6	+	0.5	+	9.14	1
Benzyl formate	Formic acid benzyl ester	104-57-4	C ₈ H ₈ O ₂	0.9	+	0.73	+	0.66	+		ne
Boron trifluoride		7637-07-2	BF ₃	NR		NR		NR		15.5	C1
Bromine		7726-95-6	Br ₂	NR	+	1.30	+	0.74	+	10.51	0.1
Bromobenzene		108-86-1	C ₆ H ₅ Br			0.6		0.5		8.98	ne
2-Bromoethyl methyl ether		6482-24-2	C ₃ H ₇ OBr			0.84	+			~10	ne
Bromoform	Tribromomethane	75-25-2	CHBr ₃	NR	+	2.5	+	0.5	+	10.48	0.5
Bromopropane, 1-	n-Propyl bromide	106-94-5	C ₃ H ₇ Br	150	+	1.5	+	0.6	+	10.18	ne
Butadiene	1,3-Butadiene, Vinyl ethylene	106-99-0	C ₄ H ₆	0.8		0.85	+	1.1		9.07	2
Butadiene diepoxide, 1,3-	1,2,3,4-Diepoxybutane	298-18-0	C ₄ H ₆ O ₂	25	+	3.5	+	1.2		~10	ne
Butanal	1-Butanal	123-72-8	C ₄ H ₈ O			1.8				9.84	
Butane		106-97-8	C ₄ H ₁₀			67	+	1.2		10.53	800
Butanol, 1-	Butyl alcohol, n-Butanol	71-36-3	C ₄ H ₁₀ O	70	+	4.7	+	1.4	+	9.99	20
Butanol, t-	tert-Butanol, t-Butyl alcohol	75-65-0	C ₄ H ₁₀ O	6.9	+	2.9	+			9.90	100
Butene, 1-	1-Butylene	106-98-9	C ₄ H ₈			0.9				9.58	ne
Butoxyethanol, 2-	Butyl Cellosolve, Ethylene glycol monobutyl ether	111-76-2	C ₆ H ₁₄ O ₂	1.8	+	1.2	+	0.6	+	<10	25
Butoxyethanol acetate	Ethanol, 2-(2-butoxyethoxy)-, acetate	124-17-4	C ₁₀ H ₂₀ O ₄			5.6				≤10.6	
Butoxyethoxyethanol	2-(2-Butoxyethoxy)ethanol	112-34-5	C ₈ H ₁₈ O ₃			4.6				≤10.6	
Butyl acetate, n-		123-86-4	C ₆ H ₁₂ O ₂			2.6	+			10	150
Butyl acrylate, n-	Butyl 2-propenoate, Acrylic acid butyl ester	141-32-2	C ₇ H ₁₂ O ₂			1.6	+	0.6	+		10
Butylamine, n-		109-73-9	C ₄ H ₁₁ N	1.1	+	1.1	+	0.7	+	8.71	C5
Butyl cellosolve	see 2-Butoxyethanol	111-76-2									
Butyl hydroperoxide, t-		75-91-2	C ₄ H ₁₀ O ₂	2.0	+	1.6	+			<10	1
Butyl mercaptan	1-Butanethiol	109-79-5	C ₄ H ₁₀ S	0.55	+	0.52	+			9.14	0.5
Carbon disulfide		75-15-0	CS ₂	4	+	1.2	+	0.44		10.07	10
Carbon tetrachloride	Tetrachloromethane	56-23-5	CCl ₄	NR	+	NR	+	1.7	+	11.47	5
Carbonyl sulfide	Carbon oxysulfide	463-58-1	COS							11.18	
Cellosolve	see 2-Ethoxyethanol										
CFC-14	see Tetrafluoromethane										
CFC-113	see 1,1,2-Trichloro-1,2,2-trifluoroethane										



Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA	
Chlorine		7782-50-5	Cl ₂					1.0	+	11.48	0.5	
Chlorine dioxide		10049-04-4	ClO ₂	NR	+	NR	+	NR	+	10.57	0.1	
Chlorobenzene	Monochlorobenzene	108-90-7	C ₆ H ₅ Cl	0.44	+	0.40	+	0.39	+	9.06	10	
Chlorobenzotrifluoride, 4-	PCBTf, OXSOL 100 p-Chlorobenzotrifluoride	98-56-6	C ₇ H ₄ ClF ₃	0.74	+	0.63	+	0.55	+	<9.6	25	
Chloro-1,3-butadiene, 2-	Chloroprene	126-99-8	C ₄ H ₅ Cl				3				10	
Chloro-1,1-difluoroethane, 1-	HCFC-142B, R-142B	75-68-3	C ₂ H ₃ ClF ₂	NR		NR		NR		12.0	ne	
Chlorodifluoromethane	HCFC-22, R-22	75-45-6	CHClF ₂	NR		NR		NR		12.2	1000	
Chloroethane	Ethyl chloride	75-00-3	C ₂ H ₅ Cl	NR	+	NR	+	1.1	+	10.97	100	
Chloroethanol	Ethylene chlorhydrin	107-07-3	C ₂ H ₅ ClO					2.9		10.52	C1	
Chloroethyl ether, 2-	bis(2-chloroethyl) ether	111-44-4	C ₄ H ₈ Cl ₂ O	8.6	+	3.0	+				5	
Chloroethyl methyl ether, 2-	Methyl 2-chloroethyl ether	627-42-9	C ₃ H ₇ ClO				3				ne	
Chloroform	Trichloromethane	67-66-3	CHCl ₃	NR	+	NR	+	3.5	+	11.37	10	
Chloro-2-methylpropene, 3-	Methallyl chloride, Isobutenyl chloride	563-47-3	C ₄ H ₇ Cl	1.4	+	1.2	+	0.63	+	9.76	ne	
Chloropicrin		76-06-2	CCl ₃ NO ₂	NR	+	~400	+	7	+	?	0.1	
Chlorotoluene, o-	o-Chloromethylbenzene	95-49-8	C ₇ H ₇ Cl			0.5		0.6		8.83	50	
Chlorotoluene, p-	p-Chloromethylbenzene	106-43-4	C ₇ H ₇ Cl					0.6		8.69	ne	
Chlorotrifluoroethene	CTFE, Chlorotrifluoroethylene Genetron 1113	79-38-9	C ₂ ClF ₃	6.7	+	3.9	+	1.2	+	9.76	5	
Chlorotrimethylsilane		75-77-4	C ₃ H ₉ ClSi	NR		NR		0.82	+	10.83	ne	
Cresol, m-	m-Hydroxytoluene	108-39-4	C ₇ H ₈ O	0.57	+	0.50	+	0.57	+	8.29	5	
Cresol, o-	o-Hydroxytoluene	95-48-7	C ₇ H ₈ O				1.0			8.50		
Cresol, p-	p-Hydroxytoluene	106-44-5	C ₇ H ₈ O				1.4			8.35		
Crotonaldehyde	<i>trans</i> -2-Butenal	123-73-9 4170-30-3	C ₄ H ₆ O	1.5	+	1.1	+	1.0	+	9.73	2	
Cumene	Isopropylbenzene	98-82-8	C ₉ H ₁₂	0.58	+	0.54	+	0.4	+	8.73	50	
Cyanogen bromide		506-68-3	CNBr	NR		NR		NR		11.84	ne	
Cyanogen chloride		506-77-4	CNCl	NR		NR		NR		12.34	C0.3	
Cyclohexane		110-82-7	C ₆ H ₁₂	3.3	+	1.4	+	0.64	+	9.86	300	
Cyclohexanol	Cyclohexyl alcohol	108-93-0	C ₆ H ₁₂ O	1.5	+	0.9	+	1.1	+	9.75	50	
Cyclohexanone		108-94-1	C ₆ H ₁₀ O	1.0	+	0.9	+	0.7	+	9.14	25	
Cyclohexene		110-83-8	C ₆ H ₁₀				0.8	+		8.95	300	
Cyclohexylamine		108-91-8	C ₆ H ₁₃ N				1.2			8.62	10	
Cyclopentane 85% 2,2-dimethylbutane 15%		287-92-3	C ₅ H ₁₀	NR	+	15	+	1.1		10.33	600	
Cyclopropylamine	Aminocyclopropane	765-30-0	C ₃ H ₇ N	1.1	+	0.9	+	0.9	+		ne	
Decamethylcyclopentasiloxane		541-02-6	C ₁₀ H ₃₀ O ₅ Si ₅	0.16	+	0.13	+	0.12	+		ne	
Decamethyltetrasiloxane		141-62-8	C ₁₀ H ₃₀ O ₃ Si ₄	0.17	+	0.13	+	0.12	+	<10.2	ne	
Decane		124-18-5	C ₁₀ H ₂₂	4.0	+	1.4	+	0.35	+	9.65	ne	
Diacetone alcohol	4-Methyl-4-hydroxy-2-pentanone	123-42-2	C ₆ H ₁₂ O ₂				0.7				50	
Dibromochloromethane	Chlorodibromomethane	124-48-1	CHBr ₂ Cl	NR	+	5.3	+	0.7	+	10.59	ne	
Dibromo-3-chloropropane, 1,2-	DBCP	96-12-8	C ₃ H ₅ Br ₂ Cl	NR	+	1.7	+	0.43	+		0.001	
Dibromoethane, 1,2-	EDB, Ethylene dibromide, Ethylene bromide	106-93-4	C ₂ H ₄ Br ₂	NR	+	1.7	+	0.6	+	10.37	ne	
Dichlorobenzene, o-	1,2-Dichlorobenzene	95-50-1	C ₆ H ₄ Cl ₂	0.54	+	0.47	+	0.38	+	9.08	25	
Dichlorodifluoromethane	CFC-12	75-71-8	CCl ₂ F ₂				NR	+	NR	11.75	1000	
Dichlorodimethylsilane		75-78-5	C ₂ H ₆ Cl ₂ Si	NR				1.1	+	>10.7	ne	
Dichloroethane, 1,2-	EDC, 1,2-DCA, Ethylene dichloride	107-06-2	C ₂ H ₄ Cl ₂				NR	+	0.6	+	11.04	10
Dichloroethene, 1,1-	1,1-DCE, Vinylidene chloride	75-35-4	C ₂ H ₂ Cl ₂				0.82	+	0.8	+	9.79	5
Dichloroethene, c-1,2-	c-1,2-DCE, <i>cis</i> -Dichloroethylene	156-59-2	C ₂ H ₂ Cl ₂				0.8				9.66	200
Dichloroethene, t-1,2-	t-1,2-DCE, <i>trans</i> -Dichloroethylene	156-60-5	C ₂ H ₂ Cl ₂				0.45	+	0.34	+	9.65	200
Dichloro-1-fluoroethane, 1,1-	R-141B	1717-00-6	C ₂ H ₃ Cl ₂ F	NR	+	NR	+	2.0	+		ne	
Dichloromethane	see Methylene chloride											



Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C IE (eV)	TWA	
Dichloropentafluoropropane	AK-225, mix of ~45% 3,3-dichloro-1,1,1,2,2-pentafluoropropane (HCFC-225ca) & ~55% 1,3-Dichloro-1,1,2,2,3-pentafluoropropane (HCFC-225cb)	442-56-0 507-55-1	C ₃ HCl ₂ F ₅	NR	+	NR	+	25	+	ne	
Dichloropropane, 1,2-		78-87-5	C ₃ H ₆ Cl ₂					0.7		10.87	75
Dichloro-1-propene, 1,3-		542-75-6	C ₃ H ₄ Cl ₂	1.3	+	0.96	+			<10	1
Dichloro-1-propene, 2,3-		78-88-6	C ₃ H ₄ Cl ₂	1.9	+	1.3	+	0.7	+	<10	ne
Dichloro-1,1,1-trifluoroethane, 2,2-	R-123	306-83-2	C ₂ HCl ₂ F ₃	NR	+	NR	+	10.1	+	11.5	ne
Dichloro-2,4,6-trifluoropyridine, 3,5-	DCTFP	1737-93-5	C ₅ Cl ₂ F ₃ N	1.1	+	0.9	+	0.8	+		ne
Dichlorvos *	Vapona; O,O-dimethyl O-dichlorovinyl phosphate	62-73-7	C ₄ H ₇ Cl ₂ O ₄ P			0.9	+			<9.4	0.1
Dicyclopentadiene	DCPD, Cyclopentadiene dimer	77-73-6	C ₁₀ H ₁₂	0.57	+	0.48	+	0.43	+	8.8	5
Diesel Fuel		68334-30-5	m.w. 226			0.9	+				11
Diesel Fuel #2 (Automotive)		68334-30-5	m.w. 216	1.3		0.7	+	0.4	+		11
Diethylamine		109-89-7	C ₄ H ₁₁ N			1	+			8.01	5
Diethylaminopropylamine, 3-		104-78-9	C ₇ H ₁₈ N ₂			1.3					ne
Diethylbenzene	See Dowtherm J										
Diethylmaleate		141-05-9	C ₈ H ₁₂ O ₄			4					ne
Diethyl sulfide	see Ethyl sulfide										
Diglyme	See Methoxyethyl ether	111-96-6	C ₆ H ₁₄ O ₃								
Diisobutyl ketone	DIBK, 2,2-dimethyl-4-heptanone	108-83-8	C ₉ H ₁₈ O	0.71	+	0.61	+	0.35	+	9.04	25
Diisopropylamine		108-18-9	C ₆ H ₁₅ N	0.84	+	0.74	+	0.5	+	7.73	5
Diketene	Ketene dimer	674-82-8	C ₄ H ₄ O ₂	2.6	+	2.0	+	1.4	+	9.6	0.5
Dimethylacetamide, N,N-	DMA	127-19-5	C ₄ H ₉ NO	0.87	+	0.8	+	0.8	+	8.81	10
Dimethylamine		124-40-3	C ₂ H ₇ N			1.5				8.23	5
Dimethyl carbonate	Carbonic acid dimethyl ester	616-38-6	C ₃ H ₆ O ₃	NR	+	~70	+	1.7	+	~10.5	ne
Dimethyl disulfide	DMDS	624-92-0	C ₂ H ₆ S ₂	0.2	+	0.20	+	0.21	+	7.4	ne
Dimethyl ether	see Methyl ether										
Dimethylethylamine	DMEA	598-56-1	C ₄ H ₁₁ N	1.1	+	1.0	+	0.9	+	7.74	~3
Dimethylformamide, N,N-	DMF	68-12-2	C ₃ H ₇ NO	0.7	+	0.7	+	0.8	+	9.13	10
Dimethylhydrazine, 1,1-	UDMH	57-14-7	C ₂ H ₈ N ₂			0.8	+	0.8	+	7.28	0.01
Dimethyl methylphosphonate	DMMP, methyl phosphonic acid dimethyl ester	756-79-6	C ₃ H ₉ O ₃ P	NR	+	4.3	+	0.74	+	10.0	ne
Dimethyl sulfate		77-78-1	C ₂ H ₆ O ₄ S	~23		~20	+	2.3	+		0.1
Dimethyl sulfide	see Methyl sulfide										
Dimethyl sulfoxide	DMSO, Methyl sulfoxide	67-68-5	C ₂ H ₆ OS			1.4	+			9.10	ne
Dioxane, 1,4-		123-91-1	C ₄ H ₈ O ₂			1.3				9.19	25
Dioxolane, 1,3-	Ethylene glycol formal	646-06-0	C ₃ H ₆ O ₂	4.0	+	2.3	+	1.6	+	9.9	20
Dowtherm A	see Therminol® *										
Dowtherm J (97% Diethylbenzene) *		25340-17-4	C ₁₀ H ₁₄			0.5					
DS-108F Wipe Solvent	Ethyl lactate/Isopar H/Propoxypropanol ~7:2:1	97-64-3 64742-48-9 1569-01-3	m.w. 118	3.3	+	1.6	+	0.7	+		ne
Epichlorohydrin	ECH Chloromethyloxirane, 1-chloro-2,3-epoxypropane	106-89-8	C ₂ H ₅ ClO	~200	+	8.5	+	1.4	+	10.2	0.5
Ethane		74-84-0	C ₂ H ₆			NR	+	15	+	11.52	ne
Ethanol	Ethyl alcohol	64-17-5	C ₂ H ₆ O			10	+	3.1	+	10.47	1000
Ethanolamine *	MEA, Monoethanolamine	141-43-5	C ₂ H ₇ NO	5.6	+	1.6	+			8.96	3
Ethene	Ethylene	74-85-1	C ₂ H ₄			9	+	4.5	+	10.51	ne
Ethoxyethanol, 2-	Ethyl cellosolve	110-80-5	C ₄ H ₁₀ O ₂			1.3				9.6	5
Ethyl acetate		141-78-6	C ₄ H ₈ O ₂			4.6	+	3.5		10.01	400
Ethyl acetoacetate		141-97-9	C ₆ H ₁₀ O ₃	1.4	+	1.2	+	1.0	+	<10	ne
Ethyl acrylate		140-88-5	C ₅ H ₈ O ₂			2.4	+	1.0	+	<10.3	5
Ethylamine		75-04-7	C ₂ H ₇ N			0.8				8.86	5



Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C IE (Ev)	TWA	
Ethylbenzene		100-41-4	C ₈ H ₁₀	0.52	+	0.52	+	0.51	+	8.77 100	
Ethyl caprylate	Ethyl octanoate	106-32-1	C ₁₀ H ₂₀ O ₂			+	0.52	+	0.51	+	
Ethylenediamine	1,2-Ethanediamine; 1,2-Diaminoethane	107-15-3	C ₂ H ₈ N ₂	0.9	+	0.8	+	1.0	+	8.6 10	
Ethylene glycol *	1,2-Ethandiol	107-21-1	C ₂ H ₆ O ₂				16	+	6	+	10.16 C100
Ethylene glycol, Acrylate	2-hydroxyethyl Acrylate	818-61-1	C ₅ H ₈ O ₃				8.2				≤10.6
Ethylene glycol dimethyl ether	1,2-Dimethoxyethane, Monoglyme	110-71-4	C ₄ H ₁₀ O ₂	1.1		0.86		0.7			9.2 ne
Ethylene glycol monobutyl ether acetate	2-Butoxyethyl acetate	112-07-2	C ₈ H ₁₆ O ₃				1.3				≤10.6
Ethylene glycol, monothio	mercapto-2-ethanol	60-24-2	C ₂ H ₆ OS				1.5				9.65
Ethylene oxide	Oxirane, Epoxyethane	75-21-8	C ₂ H ₄ O				13	+	3.5	+	10.57 1
Ethyl ether	Diethyl ether	60-29-7	C ₄ H ₁₀ O				1.1	+	1.7		9.51 400
Ethyl 3-ethoxypropionate	EEP	763-69-9	C ₇ H ₁₄ O ₃	1.2	+	0.75	+				ne
Ethyl formate		109-94-4	C ₃ H ₆ O ₂						1.9		10.61 100
Ethylhexyl acrylate, 2-	Acrylic acid 2-ethylhexyl ester	103-11-7	C ₁₁ H ₂₀ O ₂				1.1	+	0.5	+	ne
Ethylhexanol	2-Ethyl-1-hexanol	104-76-7	C ₈ H ₁₈ O				1.9				≤10.6
Ethylidenenorbornene	5-Ethylidene bicyclo(2,2,1)hept-2-ene	16219-75-3	C ₉ H ₁₂	0.4	+	0.39	+	0.34	+		≤8.8 ne
Ethyl (S)-(-)-lactate see also DS-108F	Ethyl lactate, Ethyl (S)-(-)-hydroxypropionate	687-47-8 97-64-3	C ₅ H ₁₀ O ₃	13	+	3.2	+	1.6	+		~10 ne
Ethyl mercaptan	Ethanethiol	75-08-1	C ₂ H ₆ S	0.60	+	0.56	+				9.29 0.5
Ethyl sulfide	Diethyl sulfide	352-93-2	C ₄ H ₁₀ S				0.5	+			8.43 ne
Formaldehyde	Formalin	50-00-0	CH ₂ O	NR	+	NR	+	1.6	+		10.87 C0.3
Formamide		75-12-7	CH ₃ NO				6.9	+	4		10.16 10
Formic acid		64-18-6	CH ₂ O ₂	NR	+	NR	+	9	+		11.33 5
Furfural	2-Furaldehyde	98-01-1	C ₅ H ₄ O ₂				0.92	+	0.8	+	9.21 2
Furfuryl alcohol		98-00-0	C ₅ H ₆ O ₂				0.80	+			<9.5 10
Gasoline #1		8006-61-9	m.w. 72				0.9	+			300
Gasoline #2, 92 octane		8006-61-9	m.w. 93	1.3	+	1.0	+	0.5	+		300
Glutaraldehyde	1,5-Pentanedial, Glutaric dialdehyde	111-30-8	C ₅ H ₈ O ₂	1.1	+	0.8	+	0.6	+		C0.05
Glycidyl methacrylate	2,3-Epoxypropyl methacrylate	106-91-2	C ₇ H ₁₀ O ₃	2.6	+	1.2	+	0.9	+		0.5
Halothane	2-Bromo-2-chloro-1,1,1-trifluoroethane	151-67-7	C ₂ HBrClF ₃						0.6		11.0 50
HCFC-22	see Chlorodifluoromethane										
HCFC-123	see 2,2-Dichloro-1,1,1-trifluoroethane										
HCFC-141B	see 1,1-Dichloro-1-fluoroethane										
HCFC-142B	see 1-Chloro-1,1-difluoroethane										
HCFC-134A	see 1,1,1,2-Tetrafluoroethane										
HCFC-225	see Dichloropentafluoropropane										
Heptane, n-		142-82-5	C ₇ H ₁₆	45	+	2.8	+	0.60	+		9.92 400
Heptanol, 4-	Dipropylcarbinol	589-55-9	C ₇ H ₁₆ O	1.8	+	1.3	+	0.5	+		9.61 ne
Hexamethyldisilazane, 1,1,1,3,3,3- *	HMDS	999-97-3	C ₆ H ₁₉ NSi ₂				0.2	+	0.2	+	~8.6 ne
Hexamethyldisiloxane	HMDSx	107-46-0	C ₆ H ₁₈ OSi ₂	0.33	+	0.27	+	0.25	+		9.64 ne
Hexane, n-		110-54-3	C ₆ H ₁₄	350	+	4.3	+	0.54	+		10.13 50
Hexanol, 1-	Hexyl alcohol	111-27-3	C ₆ H ₁₄ O	9	+	2.5	+	0.55	+		9.89 ne
Hexene, 1-		592-41-6	C ₆ H ₁₂				0.8				9.44 30
HFE-7100	see Methyl nonafluorobutyl ether										
Histoclear (Histo-Clear)	Limonene/corn oil reagent		m.w. ~136	0.5	+	0.4	+	0.3	+		ne
Hydrazine *		302-01-2	H ₄ N ₂	>8	+	2.6	+	2.1	+		8.1 0.01
Hydrazoic acid	Hydrogen azide		HN ₃								10.7
Hydrogen	Synthesis gas	1333-74-0	H ₂	NR	+	NR	+	NR	+		15.43 ne
Hydrogen cyanide	Hydrocyanic acid	74-90-8	HCN	NR	+	NR	+	NR	+		13.6 C4.7
Hydrogen iodide *	Hydriodic acid	10034-85-2	HI				~0.6*				10.39
Hydrogen peroxide		7722-84-1	H ₂ O ₂	NR	+	NR	+	NR	+		10.54 1
Hydrogen sulfide		7783-06-4	H ₂ S	NR	+	3.3	+	1.5	+		10.45 10
Hydroxypropyl methacrylate		27813-02-1 923-26-2	C ₇ H ₁₂ O ₃	9.9	+	2.3	+	1.1	+		ne
Iodine *		7553-56-2	I ₂	0.1	+	0.1	+	0.1	+		9.40 C0.1





Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Iodomethane	Methyl iodide	74-88-4	CH ₃ I	0.21	+	0.22	+	0.26	+	9.54	2
Isoamyl acetate	Isopentyl acetate	123-92-2	C ₇ H ₁₄ O ₂	10.1		2.1		1.0		<10	100
Isobutane	2-Methylpropane	75-28-5	C ₄ H ₁₀			100	+	1.2	+	10.57	ne
Isobutanol	2-Methyl-1-propanol	78-83-1	C ₄ H ₁₀ O	19	+	3.8	+	1.5		10.02	50
Isobutene	Isobutylene, Methyl butene	115-11-7	C ₄ H ₈	1.00	+	1.00	+	1.00	+	9.24	Ne
Isobutyl acrylate	Isobutyl 2-propenoate	106-63-8	C ₇ H ₁₂ O ₂			1.5	+	0.60	+		Ne
Isoflurane	1-Chloro-2,2,2-trifluoroethyl difluoromethyl ether, forane	26675-46-7	C ₃ H ₂ ClF ₅ O	NR	+	NR	+	48	+	~11.7	Ne
Isooctane	2,2,4-Trimethylpentane	540-84-1	C ₈ H ₁₈			1.2				9.86	ne
Isopar E Solvent	Isoparaffinic hydrocarbons	64741-66-8	m.w. 121	1.7	+	0.8	+				Ne
Isopar G Solvent	Photocopier diluent	64742-48-9	m.w. 148			0.8	+				Ne
Isopar K Solvent	Isoparaffinic hydrocarbons	64742-48-9	m.w. 156	0.9	+	0.5	+	0.27	+		Ne
Isopar L Solvent	Isoparaffinic hydrocarbons	64742-48-9	m.w. 163	0.9	+	0.5	+	0.28	+		Ne
Isopar M Solvent	Isoparaffinic hydrocarbons	64742-47-8	m.w. 191			0.7	+	0.4	+		Ne
Isopentane	2-Methylbutane	78-78-4	C ₅ H ₁₂			8.2					Ne
Isophorone		78-59-1	C ₉ H ₁₄ O					3		9.07	C5
Isoprene	2-Methyl-1,3-butadiene	78-79-5	C ₅ H ₈	0.69	+	0.63	+	0.60	+	8.85	Ne
Isopropanol	Isopropyl alcohol, 2-propanol, IPA	67-63-0	C ₃ H ₈ O	500	+	6.0	+	2.7		10.12	200
Isopropyl acetate		108-21-4	C ₅ H ₁₀ O ₂			2.6				9.99	100
Isopropyl ether	Diisopropyl ether	108-20-3	C ₆ H ₁₄ O			0.8				9.20	250
Jet fuel JP-4	Jet B, Turbo B, F-40 Wide cut type aviation fuel	8008-20-6 + 64741-42-0	m.w. 115			1.0	+	0.4	+		Ne
Jet fuel JP-5	Jet 5, F-44, Kerosene type aviation fuel	8008-20-6 + 64747-77-1	m.w. 167			0.6	+	0.5	+		29
Jet fuel JP-8	Jet A-1, F-34, Kerosene type aviation fuel	8008-20-6 + 64741-77-1	m.w. 165			0.6	+	0.3	+		30
Jet fuel A-1 (JP-8)	F-34, Kerosene type aviation fuel	8008-20-6 + 64741-77-1	m.w. 145			0.67					34
Jet Fuel TS	Thermally Stable Jet Fuel, Hydrotreated kerosene fuel (R)-(+)-Limonene	8008-20-6 + 64742-47-8 5989-27-5	m.w. 165 C ₁₀ H ₁₆	0.9	+	0.6	+	0.3	+		30
Limonene, D- Kerosene C10-C16 petro.distillate – see Jet Fuels		8008-20-6				0.33	+			~8.2	Ne
MDI – see 4,4'-Methylenebis(phenylisocyanate)											
Maleic anhydride	2,5-Furandione	108-31-6	C ₄ H ₂ O ₃							~10.8	0.1
Mesitylene	1,3,5-Trimethylbenzene	108-67-8	C ₉ H ₁₂	0.36	+	0.35	+	0.3	+	8.41	25
Methallyl chloride	– see 3-Chloro-2-methylpropene										
Methane	Natural gas	74-82-8	CH ₄	NR	+	NR	+	NR	+	12.61	Ne
Methanol	Methyl alcohol, carbinol	67-56-1	CH ₄ O	NR	+	NR	+	2.5	+	10.85	200
Methoxyethanol, 2-	Methyl cellosolve, Ethylene glycol monomethyl ether	109-86-4	C ₃ H ₈ O ₂	4.8	+	2.4	+	1.4	+	10.1	5
Methoxyethoxyethanol, 2-	2-(2-Methoxyethoxy)ethanol Diethylene glycol monomethyl ether	111-77-3	C ₇ H ₁₆ O	2.3	+	1.2	+	0.9	+	<10	Ne
Methoxyethyl ether, 2-	bis(2-Methoxyethyl) ether, Diethylene glycol dimethyl ether, Diglyme	111-96-6	C ₆ H ₁₄ O ₃	0.64	+	0.54	+	0.44	+	<9.8	Ne
Methyl acetate		79-20-9	C ₃ H ₆ O ₂	NR	+	6.6	+	1.4	+	10.27	200
Methyl acrylate	Methyl 2-propenoate, Acrylic acid methyl ester	96-33-3	C ₄ H ₆ O ₂			3.7	+	1.2	+	(9.9)	2
Methylamine	Aminomethane	74-89-5	CH ₅ N			1.2				8.97	5
Methyl amyl ketone	MAK, 2-Heptanone, Methyl pentyl ketone	110-43-0	C ₇ H ₁₄ O	0.9	+	0.85	+	0.5	+	9.30	50
Methyl bromide	Bromomethane	74-83-9	CH ₃ Br	110	+	1.7	+	1.3	+	10.54	1
Methyl t-butyl ether	MTBE, <i>tert</i> -Butyl methyl ether	1634-04-4	C ₅ H ₁₂ O			0.9	+			9.24	40
Methyl cellosolve	see 2-Methoxyethanol										
Methyl chloride	Chloromethane	74-87-3	CH ₃ Cl	NR	+	NR	+	0.74	+	11.22	50
Methylcyclohexane		107-87-2	C ₇ H ₁₄	1.6	+	0.97	+	0.53	+	9.64	400
Methylene bis(phenylisocyanate), 4,4'- *	MDI, Mondur M		C ₁₅ H ₁₀ N ₂ O ₂							Very slow ppb level response	0.005



Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Methylene chloride	Dichloromethane	75-09-2	CH ₂ Cl ₂	NR	+	NR	+	0.89	+	11.32	25
Methyl ether	Dimethyl ether	115-10-6	C ₂ H ₆ O	4.8	+	3.1	+	2.5	+	10.03	Ne
Methyl ethyl ketone	MEK, 2-Butanone	78-93-3	C ₄ H ₈ O	0.86	+	0.9	+	1.1	+	9.51	200
Methylhydrazine	Monomethylhydrazine, Hydrazomethane	60-34-4	C ₂ H ₆ N ₂	1.4	+	1.2	+	1.3	+	7.7	0.01
Methyl isoamyl ketone	MIAK, 5-Methyl-2-hexanone	110-12-3	C ₇ H ₁₄ O	0.8	+	0.76	+	0.5	+	9.28	50
Methyl isobutyl ketone	MIBK, 4-Methyl-2-pentanone	108-10-1	C ₆ H ₁₂ O	0.9	+	0.8	+	0.6	+	9.30	50
Methyl isocyanate	CH ₃ NCO	624-83-9	C ₂ H ₃ NO	NR	+	4.6	+	1.5	+	10.67	0.02
Methyl isothiocyanate	CH ₃ NCS	551-61-6	C ₂ H ₃ NS	0.5	+	0.45	+	0.4	+	9.25	ne
Methyl mercaptan	Methanethiol	74-93-1	CH ₄ S	0.65		0.54		0.66		9.44	0.5
Methyl methacrylate		80-62-6	C ₅ H ₈ O ₂	2.7	+	1.5	+	1.2	+	9.7	100
Methyl nonafluorobutyl ether	HFE-7100DL	163702-08-7, 163702-07-6	C ₅ H ₃ F ₉ O			NR	+	~35	+		ne
Methyl-1,5-pentanediamine, 2-(coats lamp) *	Dytek-A amine, 2-Methyl pentamethylenediamine	15520-10-2	C ₆ H ₁₆ N ₂			~0.6	+			<9.0	ne
Methyl propyl ketone	MPK, 2-Pentanone	107-87-9	C ₅ H ₁₂ O			0.93	+	0.79	+	9.38	200
Methyl-2-pyrrolidinone, N-	NMP, N-Methylpyrrolidone, 1-Methyl-2-pyrrolidinone, 1-Methyl-2-pyrrolidone	872-50-4	C ₅ H ₉ NO	1.0	+	0.8	+	0.9	+	9.17	ne
Methyl salicylate	Methyl 2-hydroxybenzoate	119-36-8	C ₈ H ₈ O ₃	1.3	+	0.9	+	0.9	+	~9	ne
Methylstyrene, α-	2-Propenylbenzene	98-83-9	C ₉ H ₁₀			0.5				8.18	50
Methyl sulfide	DMS, Dimethyl sulfide	75-18-3	C ₂ H ₆ S	0.49	+	0.44	+	0.46	+	8.69	ne
Mineral spirits	Stoddard Solvent, Varsol 1, White Spirits	8020-83-5 8052-41-3 68551-17-7	m.w. 144	1.0		0.69	+	0.38	+		100
Mineral Spirits - Viscor 120B Calibration Fluid, b.p. 156-207°C		8052-41-3	m.w. 142	1.0	+	0.7	+	0.3	+		100
Monoethanolamine - see Ethanolamine											
Mustard *	HD, Bis(2-chloroethyl) sulfide	505-60-2 39472-40-7 68157-62-0	C ₄ H ₈ Cl ₂ S			0.6					0.0005
Naphtha - see VM & P Naptha											
Naphthalene	Mothballs	91-20-3	C ₁₀ H ₈	0.45	+	0.42	+	0.40	+	8.13	10
Nickel carbonyl (in CO)	Nickel tetracarbonyl	13463-39-3	C ₄ NiO ₄			0.18				<8.8	0.001
Nicotine		54-11-5	C ₁₀ H ₁₄ N ₂			2.0				≤10.6	
Nitric oxide		10102-43-9	NO	~6		5.2	+	2.8	+	9.26	25
Nitrobenzene		98-95-3	C ₆ H ₅ NO ₂	2.6	+	1.9	+	1.6	+	9.81	1
Nitroethane		79-24-3	C ₂ H ₅ NO ₂					3		10.88	100
Nitrogen dioxide		10102-44-0	NO ₂	23	+	16	+	6	+	9.75	3
Nitrogen trifluoride		7783-54-2	NF ₃	NR		NR		NR		13.0	10
Nitromethane		75-52-5	CH ₃ NO ₂					4		11.02	20
Nitropropane, 2-		79-46-9	C ₃ H ₇ NO ₂					2.6		10.71	10
Nonane		111-84-2	C ₉ H ₂₀			1.4				9.72	200
Norpar 12	n-Paraffins, mostly C ₁₀ -C ₁₃	64771-72-8	m.w. 161	3.2	+	1.1	+	0.28	+		ne
Norpar 13	n-Paraffins, mostly C ₁₃ -C ₁₄	64771-72-8	m.w. 189	2.7	+	1.0	+	0.3	+		ne
Octamethylcyclotetrasiloxane		556-67-2	C ₈ H ₂₄ O ₄ Si ₄	0.21	+	0.17	+	0.14	+		ne
Octamethyltrisiloxane		107-51-7	C ₈ H ₂₄ O ₂ Si ₃	0.23	+	0.18	+	0.17	+	<10.0	ne
Octane, n-		111-65-9	C ₈ H ₁₈	13	+	1.8	+			9.82	300
Octene, 1-		111-66-0	C ₈ H ₁₆	0.9	+	0.75	+	0.4	+	9.43	75
Pentane		109-66-0	C ₅ H ₁₂	80	+	8.4	+	0.7	+	10.35	600
Peracetic acid *	Peroxyacetic acid, Acetyl hydroperoxide	79-21-0	C ₂ H ₄ O ₃	NR	+	NR	+	2.3	+		ne
Peracetic/Acetic acid mix *	Peroxyacetic acid, Acetyl hydroperoxide	79-21-0	C ₂ H ₄ O ₃			50	+	2.5	+		ne
Perchloroethene	PCE, Perchloroethylene, Tetrachloroethylene	127-18-4	C ₂ Cl ₄	0.69	+	0.57	+	0.31	+	9.32	25
PGME	Propylene glycol methyl ether, 1-Methoxy-2-propanol	107-98-2	C ₆ H ₁₂ O ₃	2.4	+	1.5	+	1.1	+		100



Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
PGMEA	Propylene glycol methyl ether acetate, 1-Methoxy-2-acetoxypropane, 1-Methoxy-2-propanol acetate	108-65-6	C ₆ H ₁₂ O ₃	1.65	+	1.0	+	0.8	+		ne
Phenol	Hydroxybenzene	108-95-2	C ₆ H ₆ O	1.0	+	1.0	+	0.9	+	8.51	5
Phosgene	Dichlorocarbonyl	75-44-5	CCl ₂ O	NR	+	NR	+	8.5	+	11.2	0.1
Phosgene in Nitrogen	Dichlorocarbonyl	75-44-5	CCl ₂ O	NR	+	NR	+	6.8	+	11.2	0.1
Phosphine (coats lamp)		7803-51-2	PH ₃	28		3.9	+	1.1	+	9.87	0.3
Photocopier Toner	Isoparaffin mix					0.5	+	0.3	+		ne
Picoline, 3-	3-Methylpyridine	108-99-6	C ₆ H ₇ N			0.9				9.04	ne
Pinene, α-		2437-95-8	C ₁₀ H ₁₆			0.31	+	0.47		8.07	ne
Pinene, β-		18172-67-3	C ₁₀ H ₁₆	0.38	+	0.37	+	0.37	+	~8	100
Piperylene, isomer mix	1,3-Pentadiene	504-60-9	C ₅ H ₈	0.76	+	0.69	+	0.64	+	8.6	100
Propane		74-98-6	C ₃ H ₈			NR	+	1.8	+	10.95	2500
Propanol, n-	Propyl alcohol	71-23-8	C ₃ H ₈ O			5		1.7		10.22	200
Propene	Propylene	115-07-1	C ₃ H ₆	1.5	+	1.4	+	1.6	+	9.73	ne
Propionaldehyde	Propanal	123-38-6	C ₃ H ₆ O			1.9				9.95	ne
Propyl acetate, n-		109-60-4	C ₅ H ₁₀ O ₂			3.5		2.3		10.04	200
Propylamine, n-	1-Propylamine, 1-Aminopropane	107-10-8	C ₃ H ₉ N	1.1	+	1.1	+	0.9	+	8.78	ne
Propylene carbonate *		108-32-7	C ₄ H ₆ O ₃			62	+	1	+	10.5	ne
Propylene glycol	1,2-Propanediol	57-55-6	C ₃ H ₈ O ₂	18		5.5	+	1.6	+	<10.2	ne
Propylene glycol propyl ether	1-Propoxy-2-propanol	1569-01-3	C ₆ H ₁₄ O ₂	1.3	+	1.0	+	1.6	+		ne
Propylene oxide	Methyloxirane	75-56-9	C ₃ H ₆ O	~240		6.6	+	2.9	+	10.22	20
		16088-62-3									
		15448-47-2									
Propyleneimine	2-Methylaziridine	75-55-8	C ₃ H ₇ N	1.5	+	1.3	+	1.0	+	9.0	2
Propyl mercaptan, 2-	2-Propanethiol, Isopropyl mercaptan	75-33-2	C ₃ H ₈ S	0.64	+	0.66	+			9.15	ne
Pyridine		110-86-1	C ₅ H ₅ N	0.78	+	0.7	+	0.7	+	9.25	5
Pyrrolidine (coats lamp)	Azacyclohexane	123-75-1	C ₄ H ₉ N	2.1	+	1.3	+	1.6	+	~8.0	ne
RR7300 (PGME/PGMEA)	70:30 PGME:PGMEA (1-Methoxy-2-propanol:1-Methoxy-2-acetoxypropane)	107-98-2	C ₄ H ₁₀ O ₂ / C ₆ H ₁₂ O ₃			1.4	+	1.0	+		ne
Sarin	GB, Isopropyl methylphosphonofluoridate	107-44-8	C ₄ H ₁₀ FO ₂ P			~3					
		50642-23-4									
Stoddard Solvent - see Mineral Spirits		8020-83-5									
Styrene		100-42-5	C ₈ H ₈	0.45	+	0.40	+	0.4	+	8.43	20
Sulfur dioxide		7446-09-5	SO ₂	NR		NR	+	NR	+	12.32	2
Sulfur hexafluoride		2551-62-4	SF ₆	NR		NR		NR		15.3	1000
Sulfuryl fluoride	Vikane	2699-79-8	SO ₂ F ₂	NR		NR		NR		13.0	5
Tabun *	Ethyl N, N-dimethylphosphoramidocyanidate	77-81-6	C ₅ H ₁₁ N ₂ O ₂ P			0.8					15ppt
Tetrachloroethane, 1,1,1,2-		630-20-6	C ₂ H ₂ Cl ₄					1.3		~11.1	ne
Tetrachloroethane, 1,1,1,2,2-		79-34-5	C ₂ H ₂ Cl ₄	NR	+	NR	+	0.60	+	~11.1	1
Tetrachlorosilane		10023-04-7	SiCl ₄	NR		NR		15	+	11.79	ne
Tetraethyl lead	TEL	78-00-2	C ₈ H ₂₀ Pb	0.4		0.3		0.2		~11.1	0.008
Tetraethyl orthosilicate	Ethyl silicate, TEOS	78-10-4	C ₈ H ₂₀ O ₄ Si			0.7	+	0.2	+	~9.8	10
Tetrafluoroethane, 1,1,1,2-	HFC-134A	811-97-2	C ₂ H ₂ F ₄			NR		NR			ne
Tetrafluoroethene	TFE, Tetrafluoroethylene, Perfluoroethylene	116-14-3	C ₂ F ₄			~15				10.12	ne
Tetrafluoromethane	CFC-14, Carbon tetrafluoride	75-73-0	CF ₄			NR	+	NR	+	>15.3	ne
Tetrahydrofuran	THF	109-99-9	C ₄ H ₈ O	1.9	+	1.7	+	1.0	+	9.41	200
Tetramethyl orthosilicate	Methyl silicate, TMOS	681-84-5	C ₄ H ₁₂ O ₄ Si	10	+	1.9	+			~10	1
Therminol® D-12 *	Hydrotreated heavy naphtha	64742-48-9	m.w. 160	0.8	+	0.51	+	0.33	+		ne
Therminol® VP-1 *	Dowtherm A, 3:1 Diphenyl oxide: Biphenyl	101-84-8	C ₁₂ H ₁₀ O			0.4	+				1
		92-52-4	C ₁₂ H ₁₀								
Toluene	Methylbenzene	108-88-3	C ₇ H ₈	0.54	+	0.50	+	0.51	+	8.82	50



Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Tolylene-2,4-diisocyanate	TDI, 4-Methyl-1,3-phenylene-2,4-diisocyanate	584-84-9	C ₉ H ₆ N ₂ O ₂	1.4	+	1.4	+	2.0	+		0.002
Trichlorobenzene, 1,2,4-	1,2,4-TCB	120-82-1	C ₆ H ₃ Cl ₃	0.7	+	0.46	+			9.04	C5
Trichloroethane, 1,1,1-	1,1,1-TCA, Methyl chloroform	71-55-6	C ₂ H ₃ Cl ₃			NR	+	1	+	11	350
Trichloroethane, 1,1,2-	1,1,2-TCA	79-00-5	C ₂ H ₃ Cl ₃	NR	+	NR	+	0.9	+	11.0	10
Trichloroethene	TCE, Trichloroethylene	79-01-6	C ₂ HCl ₃	0.62	+	0.54	+	0.43	+	9.47	50
Trichloromethylsilane	Methyltrichlorosilane	75-79-6	CH ₃ Cl ₃ Si	NR		NR		1.8	+	11.36	ne
Trichlorotrifluoroethane, 1,1,2-	CFC-113	76-13-1	C ₂ Cl ₃ F ₃			NR		NR		11.99	1000
Triethylamine	TEA	121-44-8	C ₆ H ₁₅ N	0.95	+	0.9	+	0.65	+	7.3	1
Triethyl borate	TEB; Boric acid triethyl ester	150-46-9	C ₆ H ₁₅ O ₃ B			2.2	+	1.1	+	~10	ne
Triethyl phosphate	Ethyl phosphate	78-40-0	C ₆ H ₁₅ O ₄ P	~50	+	3.1	+	0.60	+	9.79	ne
Trifluoroethane, 1,1,2-		430-66-0	C ₂ H ₃ F ₃					34		12.9	ne
Trimethylamine		75-50-3	C ₃ H ₉ N			0.9				7.82	5
Trimethylbenzene, 1,3,5- - see Mesitylene		108-67-8									25
Trimethyl borate	TMB; Boric acid trimethyl ester, Boron methoxide	121-43-7	C ₃ H ₉ O ₃ B			5.1	+	1.2	+	10.1	ne
Trimethyl phosphate	Methyl phosphate	512-56-1	C ₃ H ₉ O ₄ P			8.0	+	1.3	+	9.99	ne
Trimethyl phosphite	Methyl phosphite	121-45-9	C ₃ H ₉ O ₃ P			1.1	+		+	8.5	2
Turpentine	Pinenes (85%) + other diisoprenes	8006-64-2	C ₁₀ H ₁₆	0.37	+	0.30	+	0.29	+	~8	20
Undecane		1120-21-4	C ₁₁ H ₂₄			2				9.56	ne
Varsol – see Mineral Spirits											
Vinyl acetate		108-05-4	C ₄ H ₆ O ₂	1.5	+	1.2	+	1.0	+	9.19	10
Vinyl bromide	Bromoethylene	593-60-2	C ₂ H ₃ Br			0.4				9.80	5
Vinyl chloride	Chloroethylene, VCM	75-01-4	C ₂ H ₃ Cl			2.0	+	0.6	+	9.99	5
Vinyl-1-cyclohexene, 4-	Butadiene dimer, 4-Ethenylcyclohexene	100-40-3	C ₈ H ₁₂	0.6	+	0.56	+			9.83	0.1
Vinylidene chloride - see 1,1-Dichloroethene											
Vinyl-2-pyrrolidinone, 1-	NVP, N-vinylpyrrolidone, 1-ethenyl-2-pyrrolidinone	88-12-0	C ₆ H ₉ NO	1.0	+	0.8	+	0.9	+		ne
Viscor 120B - see Mineral Spirits - Viscor 120B Calibration Fluid											
V. M. & P. Naphtha	Ligroin; Solvent naphtha; Varnish maker's & painter's naphtha	64742-89-8	m.w. 111 (C ₈ -C ₉)	1.7	+	0.97	+				300
Xylene, m-	1,3-Dimethylbenzene	108-38-3	C ₈ H ₁₀	0.50	+	0.44	+	0.40	+	8.56	100
Xylene, o-	1,2-Dimethylbenzene	95-47-6	C ₈ H ₁₀	0.56	+	0.46	+	0.43		8.56	100
Xylene, p-	1,4-Dimethylbenzene	106-42-3	C ₈ H ₁₀	0.48	+	0.39	+	0.38	+	8.44	100
None				1		1		1			
Undetectable				1E+6		1E+6		1E+6			

* Compounds indicated in green can be detected using a MiniRAE 2000 or ppbRAE/+ with slow response, but may be lost by adsorption on a MultiRAE or EntryRAE. Response on multi-gas meters can give an indication of relative concentrations, but may not be quantitative and for some chemicals no response is observed.

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Appendix I:

Example of Automatic Calculation of Correction Factors, TLVs and Alarm Limits for Mixtures
(Calculations performed using Excel version of this database, available on request)

Compound	CF 9.8 eV	CF 10.6 eV	CF 11.7eV	Mol. Frac	Conc ppm	TLV ppm	STEL Ppm
Benzene	0.55	0.53	0.6	0.01	1	0.5	2.5
Toluene	0.54	0.5	0.51	0.06	10	50	150
Hexane, n-	300	4.3	0.54	0.06	10	50	150
Heptane, n-	45	2.8	0.6	0.28	50	400	500
Styrene	0.45	0.4	0.42	0.06	10	20	40
Acetone	1.2	1.1	1.4	0.28	50	750	1000
Isopropanol	500	6	2.7	0.28	50	400	500
None	1	1	1	0.00	0	1	
Mixture Value:	2.1	1.5	0.89	1.00	181	56	172
TLV Alarm Setpoint when Calibrated to Isobutylene:	26 ppm	37 ppm	62 ppm		181 ppm	56 ppm	172 ppm
STEL Alarm Setpoint, same Calibration	86 ppm	115 ppm	193 ppm				

SAMPLE PACKAGING AND SHIPMENT CALIBRE STANDARD OPERATING PROCEDURES

1.0 POLICY

It is the policy of CALIBRE that any individual labeling, packing and shipping packages samples from job sites will abide by the procedures outlined in this document. These procedures are designed to meet or exceed guidelines set forth by the Department of Transportation (DOT) for the shipment of potentially hazardous samples from environmental sites.

2.0 PURPOSE

This Standard Operating Procedure (SOP) provides instructions that are to be followed in the packaging, labeling, and shipment of samples collected during field operations.

3.0 INTRODUCTION

As with all field work, the ease and efficiency with which sample handling is conducted is proportional to the amount of preparation before entering the field. Organization and a thorough understanding of the sampling plan are essential for the person designated to complete paperwork and ship samples. Sufficient amounts of packaging materials must be assembled, shipping requirements determined, and shipping offices located before the trip.

While the completion of some of the paperwork in the office is advisable, this practice must be tempered by judgment. The completion of too much paperwork can be a problem if sampling plans or circumstances change in the field. Each person must determine the balance between too much and too little pre-field paperwork and preparation through experience.

Sample packaging, labeling, and shipment procedures are designed (1) to preserve sample quality so that analyses will yield results representative of site conditions, (2) to protect and inform sample handlers, including shippers and laboratory personnel, and (3) to provide a paper trail to allow cross referencing of sample collection locations with analytical results. For the purpose of sample packaging and shipment, samples are categorized as “hazardous” samples unless it can be reasonably assumed that dioxins are not present and all other contaminants are at concentrations below 10 ppm. If both these conditions are met, the sample can be packaged and shipped as an “environmental” sample. If the contaminants are known, higher limits may qualify as “environmental” samples. Procedures for handling these two types of samples follow.

4.0 PREPARATION FOR FIELD WORK

- Determine sample locations.
- Determine number of samples (including QA/QC samples).
- Determine analyses required.
- Number stations unambiguously.
- Determine probable concentrations of samples.
- Determine number and type of sample bottles required.
- Determine packaging materials required (e.g., strapping tape, ice chests, bubble wrap, etc.).
- Contact all interested parties (e.g., USACE, EPA, state agencies, site owners, site operators, etc.).

- Assemble sample bottles and packaging materials.
- Check applicable United States Department of Transportation (USDOT) shipping regulations.
- Make plans for sample shipments (e.g., locate Fed-Ex, obtain laboratory address, etc.).
- To avoid confusion, prior to sampling, bottles can be temporarily numbered with station numbers.
- Plan for likely site conditions (e.g., hazards on the site, weather, accessibility of the site, etc.).

5.0 SAMPLE HANDLING

Once samples have been sealed in the ice chests, they are to be expeditiously transported to the analytical laboratory. If the laboratory is located near the sampling site, the sampling team may drive the samples to the laboratory. Otherwise, samples are to be routinely shipped by the overnight service.

There are two types of airbills, the nonrestricted materials airbill for the shipment of environmental samples and the restricted articles airbill for the shipment of hazardous materials. Environmental samples are generally collected from sources not expected to show significant contamination, e.g., ponds, streams, and off-site soils. Samples from obviously contaminated sources such as on-site soils and groundwater, drums, leachate, and tanks must be considered as hazardous materials and shipped according to USDOT regulation. If enough information is known about a site to determine that any contamination is present at sufficiently low concentrations, then samples from these sources may be shipped as low level environmental samples.

5.1 Packaging

Samples suspected of containing dioxins at any concentrations, or suspected of containing other hazardous contaminants at concentrations over 10 ppm are to be overpacked and shipped according to USDOT regulations. The following procedure is to be used for environmental sample packaging.

- Decontaminate outside of sample containers.
- Affix sample labels to corresponding sample containers.
- Add preservatives to water samples as required.
- Use ziplock bubble baggies to protect glass sample bottles and jars.
- Enclose all other sample containers in sealed ziplock baggies.
- Place bagged sample containers in an ice chest lined with bubble wrap, checking against chain-of-custody record to ensure all samples are listed and are in the correct ice chest.
- Fill 1 to 3 ziplock bags with ice and include in the ice chest shipment if required by sampling and analysis plan. All ice should be double bagged in heavy-duty ziplock bags.
- Add packing material to ice chest to fill any remaining space.
- Detach and retain the pink copy of the chain-of-custody form.
- Seal remaining two copies of the chain-of-custody in a ziplock bag. Tape the bag to the inside of the ice chest lid.
- Affix airbill or airbill sticker to outside of the ice chest.
- Ensure “This End Up” is written or affixed onto all four sides of the ice chest.
- Ensure “Fragile” is written on two sides of the ice chest.

- Seal the ice chest with two custody seals (one on the front and one on the back). Place one layer of clear packaging tape over the custody seals.
- Tape ice chest shut using three rounds of strapping tape on either end.
- Affix shipping labels to all ice chests.
- Remove extraneous stickers from the ice chest.
- Ensure that ice chests have a return address on them.

Before relying on a shipping service, call that service to locate the drop off point nearest the site, then call that site to obtain the business hours and prepare them for your shipment. Occasionally, service operators are not aware that they can ship environmental or hazardous samples and it is inconvenient to have them attempt to learn the procedures just before the shipment deadline. Also, the shipping deadline for laboratories on the East Coast may be several hours earlier than the West Coast deadline. Calling in advance can identify these considerations.

5.2 Custody Seal

This form is used to show that no tampering of the samples has occurred between the time the samples leave the field personnel and the time when they arrive at the laboratory.

5.3 Environmental Samples Airbill

Federal Express is used to ship the vast majority of samples to analytical laboratories. This section describes the procedures used when shipping samples via Federal Express. However, this does not prevent samplers from utilizing other carriers.

Federal Express requires a completed “Nonrestricted Materials Airbill” for the shipment of environmental samples. A separate airbill is required for each destination but multiple ice chests can be shipped under one airbill if they are being sent to the same laboratory. The Federal Express Nonrestricted Materials Airbill is completed as follows.

- | | | |
|-----|-------------------------------|---|
| (1) | Date | The date the samples are shipped. |
| | Sender’s FedEx Account Number | CALIBRE FedEx account number should be printed here. |
| | Sender’s Name | Sample team leader’s name. |
| | Phone | Phone number of sample team’s office. |
| | Company | CALIBRE followed by sample team office address. |
| (2) | Internal Billing Reference | Project/task number. |
| (3) | Recipient | Name of laboratory contact, laboratory name, phone number, and address. |
| (4) | Service | Check “FedEx Standard Overnight” box. |

- (5) Packaging Check "Other Pkg." Box.
- (6) Special Handling Check "No" box.
- (7) Payment Check "Sender" box.
- (8) Release Signature Leave blank, do not sign.

5.4 Hazardous Materials Airbills

Unlike the regular airbill, the Dangerous Goods or Restricted Articles airbill has two parts. In addition to the upper portion, which is identical to the regular airbill, the Restricted Articles airbill has a lower portion entitled "Shipper's Certification for Dangerous Goods". Every effort must be made to fill out this portion correctly, as shippers may be subject to fines for the improper transport of restricted articles.

- (1-5) These sections are filled out in the same way as the regular airbill.
- (6) Check the box labeled "49 CFR".
- (7) Write in the number of ice chests being shipped on that airbill.
- (8) Proper Shipping Name One of the following will usually apply; Solid, NOS", "Flammable Liquid, NOS", "Flammable Solid, NOS", "Compressed Gas, NOS", "Corrosive", or "Hydrogen". Regulations require that the hazardous constituents must be entered along with the NOS designation (i.e., "Compressed Gas, NOS [0.1% hexane in air]).
- (9) Class or Division One of the following will usually apply;" Nonflammable Gas", "Flammable Liquid", "Flammable Solid", or "Flammable Gas".
- (10) UN or NA Number Consult USDOT Tables for proper UN or NA number. UN numbers should be written "UN1992" not "1992".
- (11) Subsidiary Risk This column is filled out when the substance has more than one hazard as listed in USDOT Tables.
- (12) Total Net Quantity Write the total quantity of hazardous materials in the shipment in appropriate units.
- (13) Radioactive Materials Check box if materials are radioactive.
- (14) Transport Details Shipping limitations as follows:
 - a. Flammable Liquids

- Less than 32 oz. – Passenger aircraft
 - 32 oz. to 10 gal. – Cargo aircraft
- b. Flammable Solids
- Less than 25 lbs. – Passenger or cargo aircraft
 - 25 lbs. To 1,000 lbs. – Cargo aircraft
 - Greater than 1,000 lbs. requires more extensive procedures.

Twenty five lbs. being the total weight of the ice chest (an empty ice chest weighs approximately 18 lbs.).

- (15) Print shipper's name and title.
- (16) Write in name of the city the shipment is being made from.
- (17) Write in telephone number of 24 hour emergency response contractor.
- (18) Shipper's signature.

5.5 Carrier Sticker

The carrier sticker is attached by carrier employees to the additional ice chests when more than one is going to the same laboratory. These are bar code stickers that are adhesive backed and are easily attached to the outside of the ice chest.

5.6 Warning Labels

USDOT regulations require warning labels for hazardous materials. USDOT regulations must be consulted and adhered to for all shipments.

6.0 SAMPLE SHIPMENT

When shipping hazardous materials (which may include samples or equipment), personnel must be aware that specific regulations govern the packaging, labeling, and transport of these items. Hazardous materials are defined by the Hazardous Materials Regulation Board and set forth in 49 CFR Parts 171-178, and must be shipped in strict accordance with USDOT procedures. CALIBRE staff members should be aware that regulatory agencies have the authority to levy substantial financial penalties on violators. These regulations apply to shipment by non-commercial (i.e., personal, rented, or company vehicles) as well as by commercial carrier. Persons making shipments should remember that only designated air carrier offices will accept hazardous materials.

6.1 Environmental Samples

Samples that are not expected to contain significant levels of contamination, such as those taken from streams, ponds, and off-site soils are considered environmental samples. That is, all low concentration samples are shipped as "Environmental Samples". These samples have no packaging, labeling, or shipping requirements beyond the usual procedures. Most air carriers require an address of the sender and of the receiver to be on the ice chest. The primary concern in the case of

“Environmental Samples” is that the samples reach their destination in a timely and undamaged state.

6.2 Hazardous Materials Samples

Samples taken from such potentially contaminated sources as on-site soils, drums, storage tanks, impoundments, lagoons, or leachates or from obviously contaminated locations must be treated as hazardous material samples and be shipped accordingly. If there is any doubt, a sample should be shipped as hazardous material. Both medium and high concentration samples are shipped as hazardous materials.

Hazardous materials must be packaged differently than the more common environmental samples. The sample is placed in a bubble baggie then placed in a metal paint can, one sample per can. The dead air space is filled with vermiculite and the can is sealed with metal clips. The paint cans are labeled with the following: Sample Tag#, Project Name, date, and any applicable warning labels. The cans are then shipped in an appropriately labeled ice chest.

6.3 Known Materials

Hazardous materials are further divided into known materials and unknown materials depending on the situation at the site. If all the hazardous substances in the sample are known or can be accurately identified, the sample is packaged, labeled, and shipped according to the instructions for that material, as detailed in the USDOT Hazardous Materials Table, 49 CFR 172.101 and the HM181 Rule – new package requirements. These change too frequently to include here.

6.4 Unknown Materials

When one or more substances in the sample cannot be identified, the sample must be shipped as an “unknown material”. The appropriate transportation procedures are determined by classifying the sample through a process of elimination using the USDOT Hazardous Materials Table.

Radioactive Materials. If radiation survey instruments indicate, or there is a reasonable suspicion the samples contain radioactive materials, they must be shipped as radioactive materials. Regulations governing transport of radioactive materials are given in 49 CFR parts 173.389 to 173.398.

Poison A. USDOT defines Poison A as extremely dangerous non-radioactive poisonous gas or liquid of such a nature that a very small amount of gas or vapor of the liquid will be dangerous to life. Most Poison A materials are gases and would not be commonly found in field activities. All samples found in closed containers do not have to be shipped as Poison A. Judgment based on available information must be used to decide if a sample is Poison A. Special efforts to be familiar with all regulations governing transport of Poison A samples should be made personally by all team leaders expecting to ship such samples. Begin with 49 CFR 173.2.

Flammable Liquids. The next two categories in the USDOT classification are flammable gas and non-flammable gas. In usual circumstances, sampling does not include gases, nor are sampling containers expected to contain a significant amount of gas in their airspace. For samples containing unknown materials, other classifications listed below flammable liquid are not usually considered. In order to classify a substance as non-flammable, a flash point test is required. Such tests would be

impractical or even dangerous in the field. Thus, unknown hazardous samples are usually shipped as flammable liquids. The phrase “flammable liquid” does not necessarily mean the sample is either flammable or a liquid; it merely refers to a shipping classification in accordance with USDOT regulations. If the sample is a solid or a sludge, it may be shipped as a “flammable solid”. Any unknown material that is not classified as Poison A, flammable gas, or nonflammable gas should be shipped as a flammable liquid or a flammable solid.

“Flammable liquid” and “flammable solid” samples must be packed in paint cans as “high” or “medium” concentration samples for shipment. The following information must be placed on each paint can:

- Laboratory name and address.
- “FLAMMABLE LIQUID, NOS UN1993” or “FLAMMABLE SOLID, NOS UN1325 (NOS means Not Otherwise Specified or Not Otherwise Stated).
- “DANGEROUS WHEN WET” if applicable.
- Sample Tag #.
- The date.

The ice chest in which the paint cans are packed should have the following labels:

- Laboratory name and address.
- “FLAMMABLE LIQUID, NOS UN1993” or “FLAMMABLE SOLID, NOS UN1325.
- “DANGEROUS WHEN WET” if applicable.
- “CARGO AIRCRAFT ONLY”.
- “LABORATORY SAMPLES”.
- “INSIDE PACKAGES COMPLY WITH PRESCRIBED SPECIFICATIONS”.
- “THIS END UP”.

Unknown hazardous materials can be transported by truck, rail, or overnight carriers, but must not be transported by passenger carrying aircraft.

7.0 SHIPMENT COORDINATION

Once samples have been shipped to the analytical laboratory, the sample team leader must notify the appropriate client and/or laboratory contact. Notification must be on the day of the shipment and if after hours, the team leader may need to leave a detailed message. The following information is to be provided:

- Team leader name.
- Telephone number for following day contact.
- Site or project name.
- Exact number of samples shipped by matrix and environmental or hazardous concentrations.
- Shipping company and airbill numbers.
- Method of shipment (overnight).
- Date of shipment.
- Analyses requested to be performed by laboratory and sample matrix.
- Any irregularities or problems with samples including special handling instructions.
- Status of sampling mission (i.e., final shipment or future sampling schedule).

SOIL SAMPLING CALIBRE STANDARD OPERATING PROCEDURES

1.0 POLICY

It is the policy of CALIBRE that any individual engaging in collection of soil samples at job sites will abide by the procedures outlined in this document. These procedures are designed to meet or exceed guidelines set forth by the Environmental Protection Agency (EPA) for the collection of representative soil samples used to determine whether concentrations of specific pollutants exceed established action levels, or if the concentrations of pollutants present a risk to public health, welfare, or the environment.

2.0 PURPOSE

This Standard Operating Procedure (SOP) provides instructions that are to be followed in collecting samples of either soil or sediments.

3.0 SOIL SAMPLING

Soil samples may be collected by either using hand tools, i.e., disposable scoop, trowel, shovel, bucket auger, or by a power driven sampling device such as a split spoon. The sample collection method should be noted in the field logbook. Samples collected for volatile organic compound analysis should be taken with Encore samplers using encore techniques.

Once the sampling location has been selected, any vegetation and/or loose material shall be removed from a circular area approximately 2 feet in diameter. The purpose of this step is to prohibit surface material from falling into the sample hole and possibly contaminating the sample. Also, a level surface will facilitate hole depth measurements.

To prevent potential surface contamination from any subsurface sample contaminants, plastic sheeting should be placed adjacent to the sample location. All subsurface material that is collected must be placed on this sheeting.

3.1 Shovel and Trowel/Scoop

When the prescribed sample depth is reasonably shallow (down to approximately 4 feet), a decontaminated shovel and disposable scoop or trowel can be used following the sequence of steps described below:

- 1) Label all jars with required tags and labels. Fill out all information except the actual date and time. Sort jars, one set per sampling location with additional sets as needed for QA/QC samples.
- 2) Note exact location of the sample in the field logbook. If possible, photograph the location.
- 3) At the time of individual sample collection, record date and time on all sample containers and in the field logbook. Cover all container labels with wide, transparent, waterproof tape to ensure label integrity.

- 4) Use a decontaminated shovel to remove the overburden to the prescribed depth and place excavated material on the plastic sheeting.
- 5) If the samples are being analyzed for volatile organic compounds (VOCs), collect the VOC fraction first. VOC sample containers should be tightly packed using a disposable scoop, leaving no airspace in the jar.
- 6) Using the scoop, fill the remaining jars at least $\frac{3}{4}$ full.
- 7) Wipe off the outside of the jar and place it in a bubble baggie. Place the bagged jar in a cooler, with ice if the sample plan calls for ice.
- 8) Replace excavated material from the plastic sheeting into hole and cap with removed vegetation or other material.
- 9) Decontaminate the sampling equipment for the next sample.
- 10) Field soil sample duplicates are to be collected either by compositing (except in the case of VOC analysis) the soil in a clean container (a composite field duplicate) or sampling from a close adjacent location (a collocated field duplicate). Follow the site-specific sample plan and document the duplicate collection process in the field logbook.

3.2 Bucket Auger

A bucket auger may be used for sample collections at intermediate depths depending on surficial geologic conditions (1 to 15 feet). Augers do not work well in rocky soils.

- 1) Label all jars with required tags and labels. Fill out all information except the actual date and time. Sort jars, one set per sampling location with additional sets as needed for QA/QC samples.
- 2) Note exact location of the sample in the field logbook. If possible, photograph the location.
- 3) At the time of individual sample collection, record date and time on all sample containers and in the field logbook. Cover all container labels with wide, transparent, waterproof tape to ensure label integrity.
- 4) On the auger, use a tape measure to locate the sample depth up from the bottom of the auger head and mark it.
- 5) Place the auger above the selected sample location and turn the "T" handle to screw the auger into the soil.
- 6) Remove the soil and repeat until sample depth is reached. Expel the soil plug by holding the auger upside down and tapping the handle on the ground. Place excavated material on a plastic sheet.
- 7) After reaching the desired depth, decontaminate the auger and remove one more soil plug. Collect the sample and place into sample containers using a disposable scoop.

- 8) If the samples are being analyzed for volatile organic compounds (VOCs), collect the VOC fraction first. VOC sample containers should be tightly packed using a disposable scoop, leaving no airspace in the jar.
- 9) Using the scoop, fill the remaining sample containers at least $\frac{3}{4}$ full.
- 10) Wipe off the outside of the jar and place it in a bubble baggie. Place the bagged jar in a cooler, with ice if the sample plan calls for ice.
- 11) Replace excavated material from the plastic sheeting or use bentonite and cement grout if downward migration of contaminants is a concern.
- 12) Decontaminate the sampling equipment for the next sample.
- 13) Field soil sample duplicates are to be collected either by compositing the soil in a gallon baggie (a composite field duplicate) or sampling from a close adjacent location (a collocated field duplicate). Follow the site-specific sample plan and document the duplicate collection process in the field logbook.

3.3 Split Spoon

A split spoon sampler is used to take subsurface soil samples by being forcefully driven into the soil at the bottom of a bore hole. Samples may be retrieved along the entire length of the bore hole to obtain an unbroken record of the subsurface layers or at selected intervals.

The split spoon is threaded on to the end of the drill rod in place of the drill bit. The bore hole may contain casing (steel or plastic pipe), depending on future use of the hole and the rigidity of the penetrated formation. The sampler is lowered on the drill rod to the bottom of the boring by heavy steel cable connected to the drilling mast. The sampler is forced into the soil by a drive weight that is dropped repeatedly onto the drive head located at the top of the drill rod. Weights up to 350 pounds are available but the most commonly used for a two-inch diameter sampler is a 140-pound weight. The weight is typically allowed to fall a distance of 30 inches. The sampler is driven into the soil to a depth that is about 6 inches shorter than the length of the sampler itself. Split spoon samplers are manufactured in 18-inch and 24-inch lengths with 2-inch to 3-inch outside diameters.

Occasionally, bedrock or extremely compacted soils are encountered that make further advance of the sampler extremely difficult or impossible without damage to the sampler. This is known as “refusal” and is defined as “penetration of less than 1 foot for 100 blows”; a blow being the act of striking the drive rod with the drive weight. Six inches for 50 blows is also commonly recognized as refusal. Upon refusal, the bore hole is to be either abandoned or the sampler removed and replaced by a drill bit.

Split spoon sample collection procedure:

- 1) Label all jars with required tags and labels. Fill out all information except the actual date and time. Sort jars, one set per sampling location with additional sets as needed for QA/QC samples.

- 2) Note exact location of the sample in the field logbook. If possible, photograph the location.
- 3) At the time of individual sample collection, record date and time on all sample containers and in the field logbook. Cover all container labels with wide, transparent, waterproof tape to ensure label integrity.
- 4) Receive sampler from driller and place on a secure bench or rack for opening.
- 5) Separate the sample tube (a flat-blade screwdriver is useful) exposing the sample or, if used, brass liners.
- 6) Run a knife between the liners to separate and immediately seal the cut ends with Teflon film if VOCs analysis is required. Wrap with Teflon plumber's tape, cap with plastic lids, and wrap with grey duct tape. Apply sample label.
- 7) If no liner is used, the sample may be collected from the open spoon using a disposable scoop.
- 8) If the samples are being analyzed for volatile organic compounds (VOCs), collect the VOC fraction first. VOC sample containers should be tightly packed using a disposable scoop, leaving no airspace in the jar.
- 9) Using the scoop, fill the remaining sample containers at least $\frac{3}{4}$ full.
- 10) Wipe off the outside of the jar and place it in a bubble baggie. Place the bagged jar in a cooler, with ice if the sample plan calls for ice.
- 11) Replace excavated material or use bentonite and cement grout if downward migration of contaminants is a concern.
- 12) Decontaminate the sampling equipment for the next sample.
- 13) Field soil sample duplicates are to be collected either by compositing the soil in a gallon baggie (a composite field duplicate) or sampling from a close adjacent location (a collocated field duplicate). Follow the site-specific sample plan and document the duplicate collection process in the field logbook.

3.4 Tube Sampler

A tube sampler may be used for collecting sediment samples underneath water. Depending on the volume of sample material desired, tubes ranging from $\frac{1}{2}$ to 2 inches can be used. The tube can be made of glass, clear plastic, PVC, or other material as appropriate for the sediment composition being sampled.

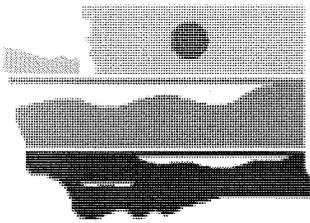
If taking both a water sample and a sediment sample, the water sample must be taken first because turbidity created in the water while taking the sediment sample would result in a non-representative water sample.

Split spoon sample collection procedure:

- 1) Label all jars with required tags and labels. Fill out all information except the actual date and time. Sort jars, one set per sampling location with additional sets as needed for QA/QC samples.
- 2) Note exact location of the sample in the field logbook. If possible, photograph the location.
- 3) At the time of individual sample collection, record date and time on all sample containers and in the field logbook. Cover all container labels with wide, transparent, waterproof tape to ensure label integrity.
- 4) Insert the tube into the sediment to the prescribed depth. Seal the top end of the tube with a gloved hand or a cap and remove the tube. The suction created causes the sediment to remain in the tube. Place sediment in the tube on plastic sheeting by removing the gloved hand or cap from the top of the tube and allowing the sediment to flow out.
- 5) If the samples are being analyzed for volatile organic compounds (VOCs), collect the VOC fraction first. VOC sample containers should be tightly packed using a disposable scoop, leaving no airspace in the jar.
- 6) Using the scoop, fill the remaining jars at least $\frac{3}{4}$ full.
- 7) Wipe off the outside of the jar and place it in a bubble baggie. Place the bagged jar in a cooler, with ice if the sample plan calls for ice.
- 8) Replace sediment from the plastic sheeting into hole.
- 9) Decontaminate the sampling equipment for the next sample.
- 10) Field sediment sample duplicates are to be collected either by compositing the sediment in a gallon baggie (a composite field duplicate) or sampling from a close adjacent location (a collocated field duplicate). Follow the site-specific sample plan and document the duplicate collection process in the field logbook.

3.5 Encore Sampling

The following attachment describes the procedures to use in Encore sampling. Note that if Encore procedures (SW 846 Method 5035A) are not used, the absence of VOCs below 200 ug/Kg cannot be demonstrated.



WASHINGTON STATE
DEPARTMENT OF
E C O L O G Y

Collecting and Preparing Soil Samples for VOC Analysis

Implementation Memorandum #5

To: Interested Parties
From: Tim Nord, Section Manager 
Date: June 17, 2004
Re: Collecting and Preparing Soil Samples for VOC Analysis

Intent of this Memorandum

The purpose of this technical memorandum is to set forth guidance regarding the implementation of Method 5035A¹. This technical memorandum provides detailed guidance on:

- How to collect soil volatile organic compound (VOC) samples;

- How to prepare and preserve soil VOC samples; and
- How to store soil VOC samples.

This guidance contains information on four methods that you may use to collect and prepare soil VOC samples for analysis. If you are collecting soil VOC samples, then you will need to use one or any combination of these four methods:

1. On-site laboratory,
2. Lab preservation,
3. Field preservation, and
4. Alternative methods.

¹ Closed-System Purge-and-Trap and Extraction for Volatile Organics in Soil and Waste Samples, EPA SW-846.



Collecting Soil Samples for VOC Analysis

Details on each of these four methods are provided in the body of this tech memo.

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What is Method 5035A?

EPA Method 5035A sets forth the requirements and procedures applicable to the collection and preparation of soil samples for volatile organic compound (VOC) analysis, including:

- Recommended or required sampling equipment (e.g., 40-mL volatile organic compound analysis (VOA) vials, etc.);
- How to collect undisturbed soil samples;

- How to preserve samples in the field by chemical (e.g., methanol) or physical (e.g., freezing) methods;
- How to transport and store samples; and
- Analytical options (i.e., low-level vs. high-level method).

Method 5035A was developed and approved for use in July 2002 by the U.S. Environmental Protection Agency (EPA). The method was included by EPA as a new method under SW-846, "Test Method for Evaluating Solid Wastes: Physical/Chemical Methods" (3rd Ed.).

When Should I Use Method 5035A?

WAC 173-340-830(3) specifies acceptable analytical methods for sites where a remedial action² is being conducted under the Model Toxics Control Act (MTCA) regulation³. EPA Method 5035A, which sets forth the requirements and procedures for the collection and preparation of soil samples for VOC analysis, is one of those methods.

Therefore, you must comply with the requirements of Method 5035A if:

- You are conducting remedial action under the MTCA cleanup regulation; and

² A "remedial action" includes remedial investigation /feasibility study (RI/FS) or site characterization (WAC 173-340-350).

³ Chapter 173-340 WAC



Collecting Soil Samples for VOC Analysis

- As part of that remedial action, you are collecting soil samples for VOC analysis.

Who is the Intended Audience for this Guidance?

The intended users of this guidance are those individuals involved in the collection and preparation of soil samples for VOC analysis, including:

- Site managers;
- Field sampling personnel;
- Laboratory analysts;
- Quality assurance personnel; and
- Data quality assessors.

The target audience for this guidance is anyone conducting petroleum- or chlorinated hydrocarbon investigations or cleanups. For example, you must use this sampling protocol for volatile hazardous substances such as benzene or trichloroethylene (TCE).

Why Do Soil VOC Samples Need to be Preserved?

A significant body of scientific evidence has found that VOCs will volatilize and biodegrade during sample collection and transport, which typically results in significant losses of initial VOC concentrations. Consequently, the consensus opinion of EPA and the scientific community is that you must take significant precautions when collecting and preparing

soil samples for VOC analysis, including the use of preservation techniques, to limit the impacts of volatilization and biodegradation. Both of these mechanisms are discussed in more detail below.

Volatilization⁴

With respect to volatilization, when VOCs are released to the soil, they immediately start to partition from the liquid phase to the gaseous phase. This rate of volatilization is compound specific. Various soil properties also impact this rate of volatilization, including grain size, moisture content, and porosity. VOCs within disaggregated or disturbed soil samples also tend to volatilize at faster rates.

In most solid materials, the molecular diffusion coefficients of VOCs in the gaseous phase are high enough to allow for the immediate volatilization of those VOCs from a freshly exposed sample surface, resulting in a loss to the surrounding atmosphere. If the sample matrix is porous, these losses will continue as VOCs below the surface diffuse outward.

In summary, the primary goal of VOC sample collection and preservation techniques is to minimize or eliminate the loss of the compounds of concern through direct volatilization to the atmosphere.

Biodegradation⁵

The biodegradation of VOCs involves compound loss by biological processes mediated by naturally-occurring organisms found within the sample. Aerobic processes

⁴ See Refs 1, 7, 9, 11, 18, 0, 27.

⁵ See Refs 8, 10, 13, 16, 17, 24.



Collecting Soil Samples for VOC Analysis

are of greatest concern, but anaerobic organisms can also result in significant compound loss. The rate of biodegradation is dependent upon several factors, including indigenous microbes, the chemical properties of the soil VOC, the original VOC concentration, and temperature.

Most soil sample collection procedures involve intrusive sampling operations that can create or enhance aerobic conditions within a sample. Aerobic conditions can occur by disaggregation of the soil particles or by simple exposure to the air. Once collected, soil VOC samples must be preserved or immediately placed in a sealed container. This must be done to minimize VOC losses from uncontrolled aerobic processes. If you do not take these precautions, then aerobic conditions will persist during handling and storage.

What is the Definition of VOC?

VOCs⁶ are organic chemicals that easily vaporize at room temperature. This includes low molecular weight aromatics, hydrocarbons, halogenated hydrocarbons, ketones, acetates, nitriles, acrylates, ethers and sulfides. Most VOCs typically have boiling points in the range of 150-200° C.

⁶ See also WAC 173-340-200 definition of VOC and EPA VOC definition in Method 5035A, Appendix A, Section A.1.1.

Should I Use this Sampling Method for Semi-volatiles?

No, you do not have to use this sampling method for semi volatiles (e.g., benzo(a)pyrene). The EPA Method 8270C is used for analyzing semi-volatiles.

Development of EPA Method 5035A

EPA Method 5035 was first published in Update III of the third edition of SW-846 on June 13, 1997. Since that time, the scientific community has continued to conduct research on soil sampling methods that minimize VOC losses. In this same time period (1997-03), EPA has also continued to provide information on issues related to Method 5035A.

On August 7, 1998, EPA published a clarification memorandum⁷ on the use of SW-846 methods, including Method 5035. In the Aug-98 memorandum, EPA recommended the following:

- As a matter of policy, all soil VOC samples should be preserved in some manner, whenever possible.
- Do not use sodium bisulfate as a preservative in calcareous soil. Use the EnCore® Sampler instead.
- If methanol is used as a preservative, then check for losses by re-weighing, in the field, sample vials that were previously weighed in the laboratory.

⁷ See Ref 6.



Collecting Soil Samples for VOC Analysis

If the difference between the laboratory/field weight is > 0.2 g, then methanol loss may have occurred and the vial should not be used.

- Use a soil-to-solvent ratio of 1:1, e.g., 5 g soil and 5 mL of methanol.

In July 2002, EPA published an update to Method 5035 in the fourth update of SW-846. The updated method is now known as Method "5035A". The updated (Jul-02) Method 5035A now contains an appendix with 32 pages of additional information.

For further information regarding the requirements of Method 5035A as well as the basis for those requirements, please refer to the method, which is available electronically ([EPA 5035A](#)).

Which Soil VOC Sampling Method Should I Select?

You will need to use one or any combination of the following four methods: 1) on-site laboratory, 2) lab preservation, 3) field preservation or 4) alternative methods.

Detailed instructions on how to collect and preserve soil VOC samples using methanol or sodium bisulfate are provided in [Appendix A: Soil VOC Sampling Instructions](#) (p. 14). Advantages and limitations of each of these four methods are discussed below.

Option 1: Mobile or On-site Labs

- The key advantage of this option is that you *don't need to preserve* any samples. You also get quantitative

information in real time, which is extremely helpful for site characterizations. The one possible disadvantage of this option is cost.

Option 2: Lab Preservation

- If you opt for lab preservation, then you will collect *unpreserved* soil VOC samples, place them on ice @ $4 \pm 2^\circ$ C and ship them to the lab for preservation and analysis. Under Method 5035A, you will ship all unpreserved samples to the lab and the lab will receive and extract the samples *within 48 hours of sample collection*. Some sampling devices (e.g., **En Core® Sampler**) require you to submit samples to the lab within 48 hours.
- **Sample containers.** You may use some type of zero headspace extraction (ZHE) container (e.g., **En Core® Sampler**) or an empty 40-mL VOA vial with 0.25 mm thick PTFE-lined septa. *Do not use core barrel liners or sample cores wrapped in aluminum foil - this will not prevent volatilization!*
- **Preservation methods.** Once the samples arrive at the lab, they must either be *preserved* or *analyzed* within 48 hours from the time of sample collection. The chemical preservation method that is used will depend on the type of analysis, i.e., low- (sodium bisulfate) or high- (methanol) concentration method. Samples that are chemically preserved in the lab must then be



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analyzed within required holding times (normally 14 days). You may also, as an option, utilize a physical preservation method by having the lab **freeze⁸ non-preserved** soil VOC samples to **$< -7^{\circ}\text{C}$** for up to **14 days**.

Note: If you do have the lab freeze samples, then the samples must be extracted with methanol only. You cannot freeze samples for the low-concentration (sodium bisulfate) method.

Advantages of Lab Preservation

- You do not need to bring preservative chemicals to the field. Also, you do not need to weigh samples prior to and after collection. Lastly, if you opt for preservation by freezing, it's convenient for the lab because the sample can be stored in a cooler for the 14-day holding time.

Limitations on Lab Preservation

- The one limitation of lab preservation is you must ship samples to the lab within **48 hours from the time of sample collection!** This does not mean, however, that the sample must be analyzed within 48 hours. What it does mean is that you must ship samples to the lab within 48 hours. The lab must then preserve the sample with sodium bisulfate, methanol, or by freezing to $< -7^{\circ}\text{C}$. If this is done within 48 hours, the holding time is 14 days.

Option 3: Field Preservation

- If you opt for field preservation, then you will collect soil VOC samples and preserve in the field by chemical preservation methods using sodium bisulfate or methanol, or by a physical preservation method such as freezing.
- **Sample containers.** If you opt for chemical field preservation, then you will be using 40-mL VOA vials with PTFE-lined septa. The vials may be pre-preserved and pre-weighed in the lab, or, you can do this in the field.
- **Preservation methods.** The chemical preservation method that you use will depend on whether you use the low- or high-concentration method. If you plan to use the low-concentration method, you must add 5 mL of sodium bisulfate to a 5 g soil sample. If you use the high-concentration method, you must add 5 mL of laboratory-grade methanol to a 5 g soil sample.

Advantages of Field Preservation

- The main advantage of field preservation is that the lab does not need to receive the samples within 48 hours.

Limitations on Field Preservation

- The main disadvantage of field preservation is that you must, in the field, do things that are normally done in laboratory. Thus, a lot more things can go wrong; however, field

⁸ See Appendix A of Method 5035, Section A.8.2.1.



Collecting Soil Samples for VOC Analysis

preservation is certainly not an impossible task, and it can be easily accomplished if you are careful and pay attention to details. For example, you must try to add a precise quantity (~ 5 mL) of preservative and soil (~ 5 g). You must also weigh sample vials prior to and after sample collection.

- You can significantly reduce error by using field kits with pre-preserved and pre-weighed vials; however, these kits can be fairly costly.
- Methanol is a toxic flammable liquid, which presents issues when collecting and shipping samples.

Option 4: Alternative Methods

- Ecology may, on a case-by-case basis, approve of alternative soil VOC sampling methods. This option is designed primarily for future changes in soil VOC sampling technology. *However, Ecology expects that as a matter of policy, all soil VOC samples must be collected in a manner that minimizes volatilization and biodegradation!*

Low- vs. High- Concentration Method: Which One Should I Select?

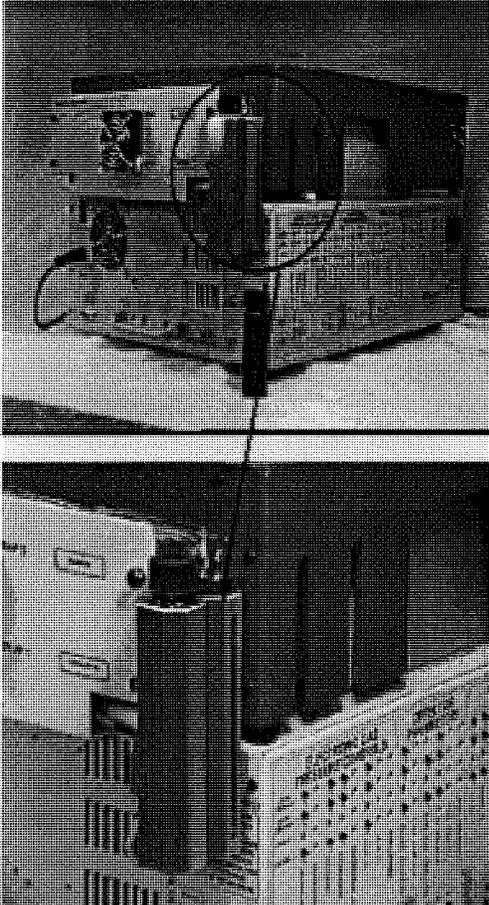
EPA Method 5035A has two main components: a “low-concentration” method and a “high-concentration” method. A brief synopsis of each is as follows:

- The low-concentration method uses sodium bisulfate as a preservative. Detection limits of < 200 ug/kg can be obtained with this method provided soil VOC concentration are < 200 ug/kg.
- The low-concentration method is designed to minimize VOC losses by using the sample container as the “purging” device (hence the name closed-system-purge and trap). Here’s how this works: when you collect the sample, it is sealed and sent to the lab. The entire sample vial is then placed, unopened, into the purge and trap “instrument carousel” (Figure 1, p.8). The vial is then heated to 40°C and the volatiles are purged into a “trap”.
- The high-concentration method uses methanol as a preservative. The high-concentration method works best for soil VOCs with concentrations > 200 ug/kg. In the high-concentration method, the lab will take a small aliquot (~ 50-100 uL) of the soil-methanol solution and inject it directly into the gas chromatograph (GC). EPA Method 8021B or 8260B is then used for analysis.



Collecting Soil Samples for VOC Analysis

Figure 1: EPA Method 5035A “Low-Concentration” Method.



Source: SRI INSTRUMENTS, 20720 Earl Street, Torrance, Calif. 90503 U.S.A.

1. UPPER PHOTO. The 40-mL VOA Vial is inserted into a Gas Chromatograph (GC) with an “Adjustable Temperature Thermostatted Sleeve”.
2. LOWER PHOTO. Two needles puncture the septum, one allowing the sparge gas (helium) to enter the

vial, the other exhausts the sample into the adsorbent traps.

The advantages and limitations of these two preparation procedures are as follows:

Low-Concentration Method Advantages

- The key advantage of this method is that it allows you to quantify soil VOCs at low concentrations, i.e., < 200 ug/kg. In particular, since you are not adding methanol, there is no dilution factor in the sample extract.

Limitations

- You are not supposed to use this method if soil VOC concentrations are > 200 ug/kg (they will likely exceed the working range of the analytical instrument).
- Because it is a closed-system-purge and trap, the lab can analyze each sample only one time. Thus, it is recommended that you collect 2-3 samples per sample location.
- Calcareous (or sandy) soil will react with the acid solution, which can result in broken or shattered VOA vials.
- Sodium bisulfate is not an efficient extraction medium for VOCs, which impacts recovery rates. This is because VOCs are less likely to dissolve into an acid solution comprised of sodium bisulfate and water.



Collecting Soil Samples for VOC Analysis

- Recent studies⁹ found that the sodium bisulfate acid solution may oxidize naturally-occurring soil waxes and humic material, which results in increased soil acetone levels.
- Methanol is a highly flammable and toxic liquid, which presents issues for shipping and sample collection. Also, methanol can be easily contaminated by atmospheric sources of VOCs, e.g., car exhaust.

High-Concentration Method Advantages

- The key advantage of this method is that VOCs will readily dissolve into methanol, which makes it a very efficient extraction medium. Studies¹⁰ on methanol extraction have found that results tended to be more accurate when compared to results from the low-concentration purge and trap method.
- Unlike the low-concentration method, the lab can analyze the sample more than once if necessary.

Limitations

- Prior to analysis, the lab must *dilute*¹¹ the sample, which means practical quantitation limits (PQLs)¹² will be *higher*. For example, if you mix add 5 mL of methanol with 5 g of soil and the lab extracts 100 uL for analysis, the dilution is 50 (5,000 uL/100 uL = 50). With a dilution of 50, you can probably expect to achieve laboratory reporting limits/PQLs of ~ 25-50 ug/kg.

How Do I Know if Soil VOC Concentrations are < or > 200 ug/kg?

If you opt for the low-concentration method, you will need to check and make sure that soil VOC concentrations are < 200 ug/kg. To do this, you may use field screening instruments¹³, or you may instruct the lab to screen samples. Also, before you make any decisions about which method to use, you should always check Ecology's soil cleanup standards. Cleanup levels for nine (9) common VOCs are provided in Table 1.

Table 1: State of Washington Method A Soil VOC Cleanup Levels (Unrestricted Land Use).

Volatile Organic Compound (VOC)	Cleanup Level (ug/kg)
Benzene	30
Ethyl Benzene	6,000
MTBE	100
Naphthalene	10,000
Tetrachloroethylene	50
Toluene	7,000
Trichloroethane-1,1,1	50
Trichloroethylene	30
Xylene	9,000

Source: Table 740-1 (Chapter 173-340 WAC)

⁹ See Refs 3, 17, 26.

¹⁰ See Refs 1, 14, 15, 18, 19, 22, 0.

¹¹ See also EPA 5035A, Section 8.2.2.

¹³ See Ref 19.



Collecting Soil Samples for VOC Analysis

WASHINGTON DEPARTMENT OF ECOLOGY

EPA Method 5035A

SOIL VOC SAMPLING

START

USE ONE OR ANY COMBINATION OF THE FOLLOWING METHODS:

MOBILE LAB

SOIL VOC SAMPLES ARE ANALYZED ON-SITE. YOU DO NOT NEED TO PRESERVE SAMPLES; HOWEVER, YOU MUST MINIMIZE VOLATILIZATION.

LAB PRESERVATION

YOU COLLECT NON-PRESERVED SAMPLES. YOU MUST TRANSPORT TO LAB WITHIN 48-HRS. THE LAB MUST EITHER:
1) PRESERVE FOR 14-DAY HOLDING TIME, OR
2) ANALYZE WITHIN 48-HRS.

FIELD PRESERVATION

YOU COLLECT SOIL VOC SAMPLES AND PRESERVE IN THE FIELD.

ALTERNATIVE METHODS

ECOLOGY REVIEWS ON A SITE-SPECIFIC BASIS. INTENDED FOR FUTURE CHANGES IN SOIL VOC SAMPLING TECHNOLOGY.



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Appendix A: Soil VOC Sampling Instructions

Appendix A: Soil VOC Sampling Instructions

OVERVIEW

The instructions provided here are **guidelines**. You are, however, legally obligated to follow and meet the criteria specified in WAC 173-340-830. We recognize and understand that sampling protocols vary and that how you do things will vary. Ecology also recognizes that with respect to analytical methods, the “performance based”¹⁴ approach is now gaining widespread acceptance. Ecology compiled these instructions based on a review of other state 5035A policies, the instructions in Method 5035A itself and consultation with others who had historical knowledge of how best to implement Method 5035A.

SOIL VOC SAMPLING INSTRUCTIONS PLEASE NOTE

If you opt for lab preservation, then you may skip STEPS 1-6 and go directly to STEP 7. The instructions provided in this tech memo are only for the sampling and preservation of soil VOC samples when using methanol or sodium bisulfate as the preservative. The instructions do not include a description of other sampling or preservation procedures, including those involving the freezing of the soil samples. For a complete description of sampling and preservation procedures see EPA Method 5035A.

¹⁴ EPA defines this as “a set of processes wherein the data quality needs, mandates or limitations of a program or project are specified, and serve as criteria for selecting appropriate methods to meet those specified needs in a cost effective manner.”



Appendix A: Soil VOC Sampling Instructions

WHAT EQUIPMENT WILL I NEED?

Laboratory Preservation

- **Sample containers.** You may use a zero Headspace Extraction (ZHE) container (e.g., **En Core® Sampler**) or other equivalent container.
- **Shipping arrangements.** Products like the En Core® sampler must be shipped to the lab within 48 hours. ***Depending upon the product you use, you must make shipping arrangements ahead of time!***

Field Preservation

- **Vials.** You must use 40-mL “VOA” glass vials with septum sealed Teflon-lined screw caps. All vials must be pre-weighed to the nearest 0.1 g. Record the vial tare weight on the sample label. You can either have the lab do this or you can do it in the field with your field balance.
- **Preservative.** If you are using the **low-concentration method**, then you must use sodium bisulfate ((NaHSO₄) preservative. You must mix the preservative (~ 1 g) with at least 5 mL of organic-free reagent water so that the pH of the acid-water solution is ≤ 2. You can either have the lab do this or you can do it in the field. If you are using the **high-concentration method**, then you will need to use laboratory-grade methanol (CH₃OH).
- *NOTE: Ecology recommends that you use pre-preserved and pre-weighed vials.*
- **Safety equipment.** Methanol is a toxic and flammable liquid. You will need to wear rubber gloves and other appropriate safety equipment.
- **Soil Sampling Syringes.** Ecology recommends that you use syringes to collect soil samples. Syringes have three distinct advantages: 1) they essentially allow you to collect **undisturbed samples**, 2) they are calibrated with marks or lines that allow you to pre-determine how much sample is equal to 5 g, and 3) most syringes are designed to prevent **headspace air** above the sample contents. You may use several types of commercially available syringes, including: En Novative Technologies Inc. EasyDraw® syringe and Powerstop Handle®, Environmental Sampling Supply (ESS) “Lock N’ Load”, etc.
- **Balance.** You will need a portable “field” balance that is capable of weighing to 0.1 g. You will also need reference weights so that you can periodically check the balance for accuracy.



Appendix A: Soil VOC Sampling Instructions

SOIL VOC SAMPLING INSTRUCTIONS

- *Note: If you opt for lab preservation, then you may skip STEPS 1-6 and go directly to STEP 7. The following instructions are only for the sampling and preservation of soil VOC samples when using methanol or sodium bisulfate as the preservative. The following instructions do not include a description of other sampling or preservation procedures, including those involving the freezing of the soil samples. For a complete description of sampling and preservation procedures see EPA Method 5035A.*

STEP 1. CHECK LOCATION

- If you are using methanol, then select an area that is free of car exhaust (it will contaminate the methanol).

STEP 2. CHECK SAFETY GEAR

- You should always wear gloves, goggles and other appropriate safety gear.
- *NOTE: methanol (Chemical Abstract Number 67-56-1) is a toxic and flammable liquid. You will need to use proper safety precautions. Ecology recommends that you wear Nitrile Rubber or Viton gloves. Avoid inhalation and make sure you store and use the methanol in a ventilated area, away from ignition sources. In the event of eye contact, flush with large volumes of water and seek medical attention immediately!*

STEP 3. CHECK FIELD BALANCE, AND FIELD-WEIGH 40-mL VOA VIALS

- a) Check the calibration of your field balance. Follow manufacturer's instructions and record the check in your field notebook.
- b) Reweigh each 40-mL VOA vial that you will be using that day. ***If the difference between the lab tare weight and the field weight is > 0.2 g, then do not use the vial!***

STEP 4. PREPARE METHANOL BLANKS

- a) Ecology recommends preparing at least one methanol blank per sample cooler. Here's how this works: while you are collecting your soil VOC samples, you will leave the blank methanol vial open to check for any atmospheric VOCs. When you are done collecting soil samples, you will cap the blank vial and ship it to the lab along with the other samples.



Appendix A: Soil VOC Sampling Instructions

- b) **Preparing a methanol blank:** check with the lab about a methanol preservation sampling kit. You will need a tube of methanol and a pre-weighed 40-mL vial. When you are ready in the field, cut off the top of the methanol tube and carefully pour the contents into the 40-mL vial. Affix a label entitled "methanol field blank". Record the identification number in your field notebook. While collecting soil VOC samples, leave the blank methanol vial open. When done collecting soil samples, cap the blank vial and ship it to the lab along with the other samples.

STEP 5. CALIBRATE SOIL SYRINGE

- a) If the syringe is already calibrated for 5 g (e.g., EasyDraw Syringe® and Powerstop Handle®; Figure 4, p. 21), then load or insert the syringe into the handle slot that is marked "5 g".
- b) If you do not have a pre-calibrated syringe, then do this:
- Weigh an empty syringe on your field balance and record the weight,
 - Insert the empty syringe into the soil and collect ~ 5 g soil. Cap the syringe. Make sure you wipe off any excess dirt.
 - Reweigh (syringe + soil) and subtract syringe weight to determine soil weight.
 - If the soil weight is ~ 5 g, then record how far you had to insert the syringe into the soil to achieve ~ 5 g. Use a trial-and-error method until you determine how far you must insert the syringe.

STEP 6. CHECK FOR CALCAREOUS SOILS

- *NOTE: this step applies only if you are using sodium bisulfate as a preservative. If you are preserving with methanol, then skip this step and go to STEP 7. If you are working in calcareous or carbonate soils, then do not use the sodium bisulfate preservative! The acid solution will react with the soil, which may result in excessive gas buildup and a shattered or broken VOA vial. If you do encounter calcareous soil, then use distilled water as a preservative! If you want to check to see if the soil contains carbonates, then squirt a few drops of hydrochloric acid (HCL) onto the soil. If it fizzes or effervesces, then the soil is calcareous.*

STEP 7. COLLECT SOIL SAMPLES

- a) As a general rule of thumb, you should probably **collect at least two samples for every one location you sample**. This is particularly true for the low-concentration (sodium bisulfate) method, as the lab can analyze the sample only one time.



Appendix A: Soil VOC Sampling Instructions

- b) If you are using a methanol blank to check for contamination, then open it and place it in a secure area. Cap the vial when you are done collecting samples.
- c) If you are using a syringe (e.g., En Core EasyDraw®) to collect samples, you will need to collect an undisturbed soil sample from a freshly exposed surface. To do this, gently push the syringe into the soil to a depth that is \cong 5 g soil (see Figure 2, p. 20). Remove the syringe from the soil and quickly wipe the barrel end clean. Immediately cap the syringe. Make sure you wipe off any excess dirt.
 - *NOTE: the En Core EasyDraw® syringe is not the same device as the En Core® Sampler! The syringe is supposed to be used only to collect and extrude soil into the VOA vial.*
- d) If you are using the En Core® Sampler, use the steel T-handle to push the sampler into the soil. Skip Step 8 and go to STEP 10.
- e) If the syringe or En Core® Sampler does not penetrate the soil, use a stainless steel spatula or scoop. Try to scoop or remove \sim 5 g soil. Once you've collected your sample, gently fill your 40-mL VOA vial with the appropriate preservative. Go to STEP 8.

STEP 8. EXTRUDE SOIL SAMPLES TO VOA VIALS AND RE-WEIGH.

- a) Remove the syringe cap and extrude the 5 g soil sample from the syringe into the 40-mL VOA vial (Figure 3, p. 20). Quickly brush off any soil from the vial threads and **immediately seal the vial with septum and screw-cap!**
 - *NOTE: once you've collected the soil sample, you must try to extrude it into the VOA vial with within 10 seconds! Before you screw the cap on, make sure you inspect the VOA vial threads and wipe off any dirt!*
- b) **Low-concentration Method.** If you are using the *low-concentration* method (soil VOCs < 200 ug/kg), then you must, for a 5 g soil sample, add \sim 1 g of sodium bisulfate (NaHSO₄) to each 40-mL vial. If you are collecting soil samples significantly < or > 5 g, then add \sim 0.2 g of preservative for 1 g of sample, e.g., 25 g sample = 5 g preservative. Add at least 5 mL of organic-free reagent water so that the pH of the acid-water solution is \leq 2.
- c) **High-concentration Method.** If you are using the *high-concentration* method (soil VOCs > 200 ug/kg), then you must add 5 g of soil with 5 mL of laboratory grade methanol (CH₃OH).
- d) Gently swirl the vial for \sim 10 seconds to break up the soil particles. **DO NOT SHAKE!**



Appendix A: Soil VOC Sampling Instructions

- e) **Re-weigh** the 40-mL vial. **Your target weight is 5 ± 0.5 g.** Record the sample weight to the nearest 0.1 g in your field notebook. **Do not record the weight on the sample label!**
- *NOTE: **do not** open the vial if you've added too much (or too little) soil. The lab can add more methanol to achieve a 1:1 ratio. The desired ratio of grams soil / mL methanol is 1:1, within a tolerance of +/- 25%. Ratios outside this range may be acceptable, depending upon data quality objectives. In all cases, however, the soil sample must be completely immersed in methanol.*

STEP 9. COLLECT ADDITIONAL SOIL SAMPLES FOR MOISTURE CONTENT ANALYSIS

- a) **For every one location you sample, you must collect at least one soil sample for moisture content analysis!** The lab must have this information so that it can normalize the soil VOC concentration to a dry-weight basis. You should collect ~ 10 g of soil for moisture content analysis. Do not add preservative to the sample designated for moisture content analysis. Use the EasyDraw® syringe, a 4-oz wide mouth glass jar, a 40-mL VOA vial, or other suitable container for your moisture content analysis. Make sure you label the vial so that the lab knows it's for moisture content analysis!
- *NOTE: Because water is completely miscible with methanol, naturally-occurring soil moisture may result in under-reporting of the true, dry-weight VOC concentrations. As a general rule of thumb, a 1% increase in moisture content (by weight) will result in a negative bias of ~ 1%; however, moisture contents < 25% by weight are generally not considered significant by most labs.*

STEP 10. ICE SAMPLES AND SHIP TO LAB

- a) **Once they are sealed and weighed, immediately place all samples on ice @ $4 \pm 2^\circ$ C!**
- b) If you are shipping methanol-preserved samples, you must comply with the following requirements:

Methanol Shipping Requirements

- Each 40-mL vial must have < 30 mL of methanol (30 mL falls under the federal exemption for small quantities of flammable liquids).
- The "cooler" or container that you use for shipping must have a total methanol volume of < 500 mL (that's 50 samples @ 10 mL of methanol each).



Appendix A: Soil VOC Sampling Instructions

- You must have sufficient absorbent material in the cooler in case one of the vials breaks. You must have enough to completely absorb the vial's contents.
- The cooler or package weight must not exceed 64 pounds.
- Each cooler or container must be clearly labeled as containing < 500 ml methanol.
- The shipping of methanol is regulated by the U.S. Department of Transportation, Title 49 of the Code of Federal Regulations. The DOT number is UN 1230.

Figure 2: Using a Syringe to Collect the Soil Sample.

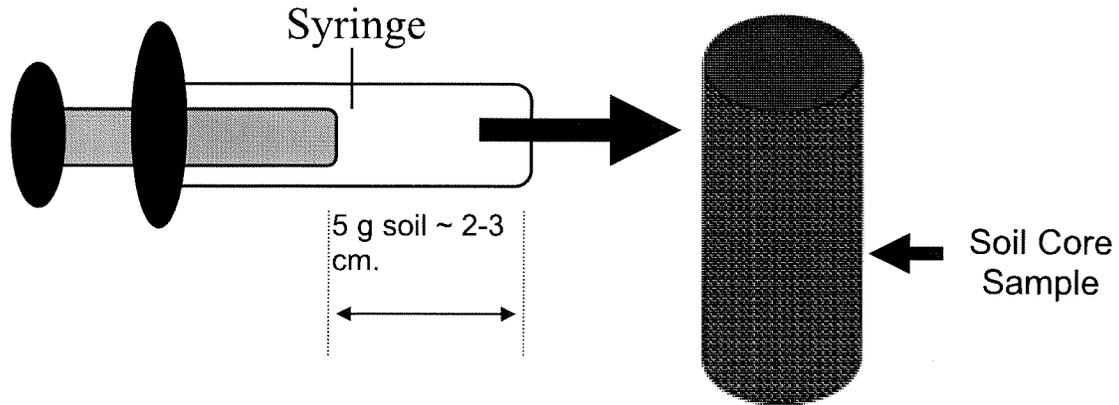


Figure 3: Vial and Sample.

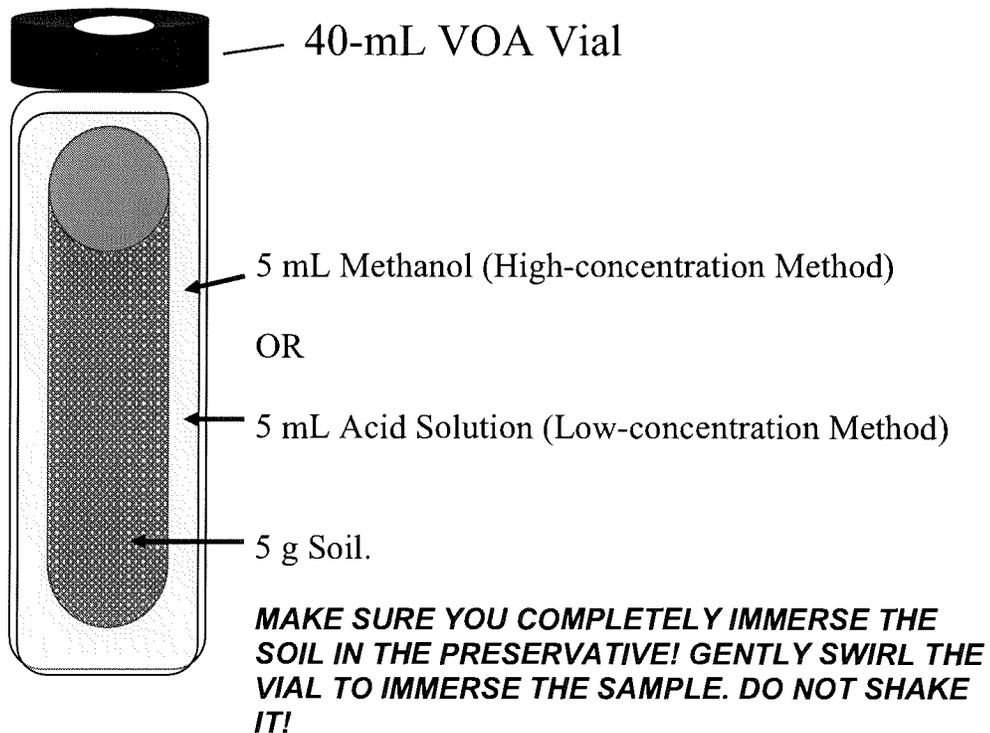
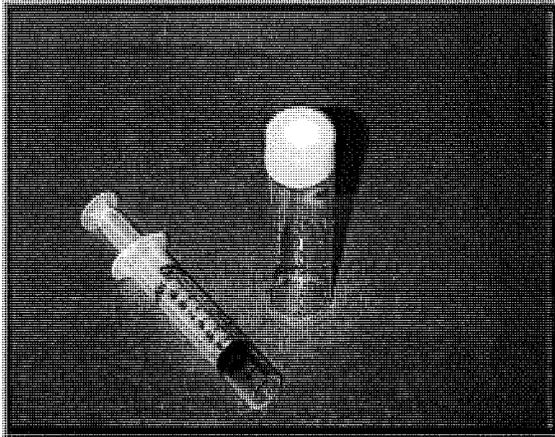
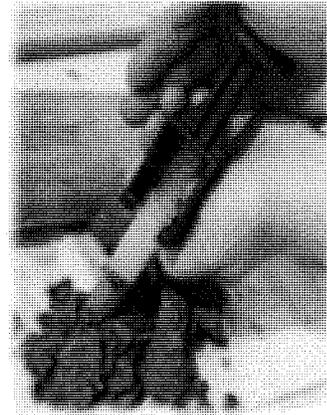


Figure 4: Sample Collection Equipment.

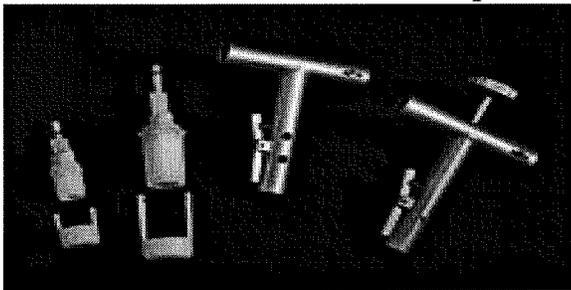
40-mL VOA Vial and Plastic Syringe



“EasyDraw® Syringe & Powerstop Handle®

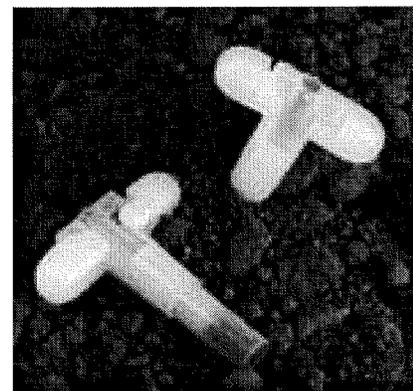


“En Core®” Soil Core Sampler



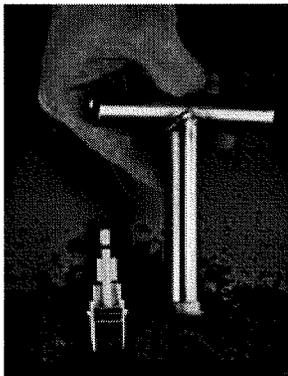
En Novative Technologies, Inc.

Terra Core™ Soil Sampler



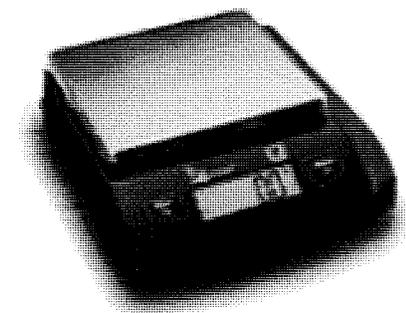
En Novative Technologies, Inc.

“En Core®” T-Handle



En Novative Technologies, Inc.

Field Balance



Portable Scout* Series Electronic Balance by Ohaus*

VAPOR SAMPLING CALIBRE STANDARD OPERATING PROCEDURES

1.0 POLICY

It is the policy of CALIBRE that any individual engaging in collection of vapor samples at job sites will abide by the procedures outlined in this document. These procedures are designed to meet or exceed guidelines set forth by the Environmental Protection Agency (EPA) for the collection of vapor samples.

2.0 PURPOSE

This Standard Operating Procedure (SOP) provides instructions that are to be followed in the collection of vapor samples (gas phase) for laboratory or field analysis of volatile organic compounds (VOCs). The purpose of this SOP is to define the use of several different air sampling techniques that can be used for soil gas monitoring, indoor air monitoring and remediation system monitoring of VOCs present as a vapor phase in air. The sampling methods discussed include sample collection with Tedlar bags, sample collection using SUMMA canisters and field testing using a Photo Ionization Detector (PID) and other vapor monitoring instruments.

3.0 INTRODUCTION

Vapor samples may be collected as part of remediation systems performance monitoring, soil gas monitoring or indoor air monitoring to provide a means of detecting volatile organic compounds (VOCs) in the specific sampling matrix. This SOP outlines the methods to be used for the collection of vapor samples using Tedlar bags and SUMMA canisters and measurement of organic vapor levels in samples using a PID.

4.0 METHOD SUMMARY

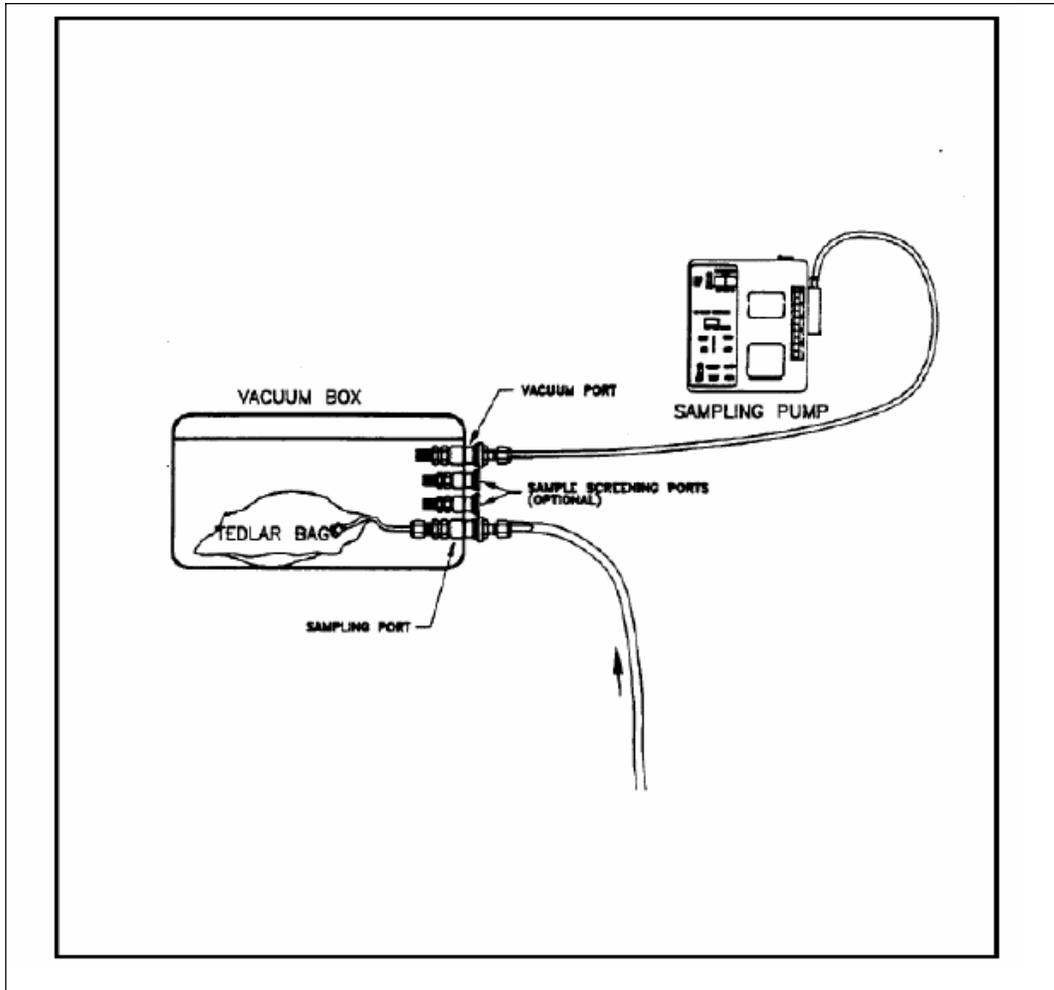
The objective of the vapor sampling procedures described herein is to collect representative gas samples of the targeted media and analyze the gas for the presence of VOCs. Typically, a low volume air pump is used to pull a sample through the sampling train.

The sample may be collected in Tedlar bags using a vacuum box (see Figure 1), or directly to the Tedlar bag depending on the sampling point (lines under pressure do not need to use a vacuum box). An air pump is not required to fill a SUMMA canister; sampling is achieved by equilibration with the evacuated SUMMA canister, however a vacuum pump may still be necessary to flush the sampling train. The sample container may then be shipped to a laboratory for analysis of VOC present.

The common laboratory analytical procedures used for analysis of VOCs in gas samples are EPA methods 8260B, T015. Both of these analytical methods utilize a GC/MS analysis. Typical detection limits for the 8260B analysis are VOCs in the range of 5-100 ug/m³. Typical detection limits for the T015 analysis are VOCs in the range of 1-10 ug/m³. Typical detection limits for the PID analysis using a Rae Systems ppb PID are the range of 100-1,000 ug/m³ (as total organic vapors).

A PID employs the principle of photoionization to detect and quantify the concentration of organic vapors present in a gas phase sample. The analyzer will respond to most vapors that have an ionization potential (IP) less than or equal to that supplied by the ionization source used in the PID, an ultraviolet (UV) lamp. Photoionization occurs when an atom or molecule absorbs a photon of sufficient energy to release an electron and form a positive ion.

Figure 1 Sampling setup using Tedlar bag in evacuated box



The ionization chamber exposed to the light source contains electrodes to create an electro-magnetic field in the chamber. Ions formed by the VOC adsorption of photons are driven to an electrode and the current produced is then measured and the corresponding concentration displayed on the meter, directly, in the units used for calibration, typically parts per million volume (ppmv) or parts per billion volume (ppbv). Though it can be calibrated to a particular compound, the instrument cannot distinguish between detectable compounds in a mixture of gases and, therefore, indicates an integrated response to the mixture (i.e., the measurement is for the total organic vapors present).

Field air monitoring devices include a Rae Systems ppb PID that reads in ppbv and a variety of other PID instruments that typically read in ppmv. Sampling with field instruments is typically completed with the sample first collected in a container, such as a Tedlar bag, and the PID instrument (or other) used to read the total organic vapor concentration in the sample.

5.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

5.1 Tedlar Bags

Vapor samples are generally collected in 1-liter (L) Tedlar bags. Bagged samples should be stored in the dark (i.e., in opaque containers) and protected from mechanical damage during transit to the laboratory. Further, samples should be maintained at ambient temperature by placing them in coolers, and out of direct ultra-violet (UV) light. Samples should be analyzed as soon as possible, particularly, if the stability of the compound is unknown. Under some conditions (typically considered to be high VOC concentrations), loss may occur either because of diffusion through the Tedlar bag or adsorption onto it.

A typical holding time for VOC analysis (using Tedlar bags for sampling) is no more than 48 hours. Because of this short holding-time, it is critical that the sampling event and shipping be coordinated with the laboratory prior to sample collection. In general, Tedlar bag samples collected for laboratory analysis must be collected on Monday/Tuesday and delivered by overnight courier to the laboratory (unless other specific arrangements have been made with the laboratory for the delivery date).

5.2 SUMMA Canisters

The SUMMA canisters used for vapor sampling have a 6-liter sample capacity and are certified clean by GC/MS analysis before being used in the field. After sampling is completed, the samples are shipped in travel cases for off-site laboratory analysis. Most VOCs can be recovered from canisters with minimal loss up to 14 days.

5.3 Field Sampling with PID (and other instruments)

A PID instrument may be used for on-site testing of the sample collected. A PID is typically used in conjunction with sample collection in a Tedlar bag. Other field instruments that may be used (depending on the site conditions, contamination present and sampling objectives) include oxygen/lower explosive limit (O₂/LEL) meters, Flame Ionization Detectors (FIDs). Examples of other field air monitoring instruments include: combustible gas indicator (MSA CGI/O₂ Meter, Model 260), organic vapor analyzer (Foxboro OVA, Model 128, Thermo electron OVA model 580), and a variety of other instruments by various manufacturers. For any instrument used on a

project, each must have the model-specific O&M manual which will specify the key details on calibration, resolution, interferences, etc.

6.0 INTERFERENCES AND POTENTIAL PROBLEMS

6.1 Factors Affecting the Sample Collected with Tedlar Bags or SUMMA Canisters

Standard laboratory analytical methods will detect VOCs at levels less than 1 part per billion volume (ppbv) in vapor phase samples. As a consequence, the potential for inadvertent sample contamination is a significant concern since many of the compounds in question are commonly used in commercial products, industries and residential settings. In order to minimize the risk of cross contamination, the following factors should be considered:

- 1) Proximity of the containers (bags/canisters) to source(s) of potential contamination during transportation and storage. Containers and the sampling train (tubing, pumps, or other) must be kept away from potential source(s) to the maximum extent feasible to minimize the chances of external contamination. All bags should remain in clean sealed containers until the time of use.
- 2) A variety of common products (many used in field sampling) will contain compounds that may be detected in the analysis. Examples include marking paint, marking pens (sharpies), fuel, adhesives, tape, and decontamination solutions from other sampling/well purging. The utmost care must be taken to minimize the potential for inadvertent contamination of the samples and sampling train.
- 3) Containers must be attached only to clean Teflon tubing.
- 4) For Tedlar bags, attach the sample label to the bag using a string or zip-tie through the eyelet on the Tedlar bag. Common adhesives found in the label may potentially permeate the bag if placed on the body of the bag.
- 5) Fill out labels using only a ballpoint pen; permanent markers contain volatile compounds that may contaminate the sample.
- 6) Due to the chemical structure of Tedlar, highly polar compounds may adhere to the inner surface of the bag. Also, low molecular weight compounds may permeate the bag.

6.2 PID Measurements

A number of factors specific to vapors associated with remediation systems and soil/indoor air vapor monitoring can affect the response of a PID. The most common problem in using a PID is rapid temperature fluctuations which may cause the PID lamp to fog; high humidity can also cause lamp fogging and decreased sensitivity. This can occur when the relative humidity of the sample collected is high such as soil vapor samples from moist/wet soils. The critical step to minimize problems associated PID lamp fogging is to keep the PID warm (such as in the heated cab of a field vehicle) if ambient conditions are wet or cold. High and low temperature, and naturally occurring compounds, such as terpene hydrocarbons in wooded areas, can affect instrument response. Always follow instructions in the instrument manual. A manual for the Rae Systems ppb PID is included as Appendix A.

Specific considerations in the use of a PID include the following:

- 1) The PID is a nonspecific total organic vapor detector. It cannot be used to identify unknown substances; it can only quantify the total organic vapors (as calibrated to isobutylene response).
- 2) The PID must be calibrated to a specific compound (or more typically include a conversion factor for equivalent response as isobutylene).
- 3) The PID does not respond to certain low molecular weight hydrocarbons, such as methane and ethane, in addition, the PID does not detect a compound if the probe has a lower energy than the compound's IP. Specific compounds (e.g., carbon tetrachloride and hydrogen cyanide, have high IPs and cannot be detected with a PID).
- 4) Certain models of PID instruments are not designed for use in potentially flammable or combustible atmospheres.
- 5) The lamp window must be periodically cleaned to ensure effective ionization of the compounds by the probe (although this step has been largely eliminated with the self cleaning process implemented the Rae Systems ppb PID).
- 6) The PID measures concentration linearly over the calibrated range, any response outside of the calibrated range cannot be reliably quantified. The Rae Systems ppb PID requires special procedures for the zero calibration.
- 7) The instrument should not to be exposed to precipitation.
- 8) Do not use the instrument for head space analysis where liquids can inadvertently be drawn into the probe.

Transport of calibration gas cylinders by passenger and cargo aircraft must comply with International Air Transport Association (IATA) Dangerous Goods Regulations or the U.S. Code of Federal Regulations, 49 CFR Parts 100-177. A typical calibration gas included with a PID is isobutylene. It is classified as a non-flammable gas, UN #1556 and the proper shipping name is Compressed Gas. It must be shipped by cargo aircraft only.

6.3 Factors Affecting the Concentrations of Organic Compounds in Soil Gas

Concentrations of organic compounds in vapor can be affected by the physical and chemical characteristics of the soil, soil moisture, and nature of the target compound. Important factors to consider include the compounds' vapor pressure, solubility and soil partitioning (typically estimated from the organic carbon adsorption coefficient K_{oc}). Soil porosity and permeability will affect the movement of soil gas and the recharge rate of the soil gas into a well. The movement of organic vapors through fine textured soil may be very slow, thus limiting the sample volume available and the use of this technique.

The presence of a high or perched water table, or of an impermeable underlying layer (such as a clay lens or layer of buried slag) may interfere with the movement and sampling of the soil gas.

7.0 EQUIPMENT/APPARATUS

7.1 Tedlar Bag Sample Collection

The following equipment must be available and operational to perform Tedlar bag sampling:

- 1) Vacuum box must be clean, Teflon tubing replaced, and equipped with extra O-rings

- 2) Pump(s) must be charged, in good working order, and set with the appropriate flow rate of 3 liters per minute
- 3) Tedlar bags must be new.
- 4) Sample documentation (sample labels, field data sheets, logbook, chain of custody records, custody seals, etc.)
- 5) Small zip-ties to affix label through eyelet on bag
- 6) Air sampling worksheets
- 7) Opaque trash bags
- 8) PID or other field air monitoring devices
- 9) Cooler(s)

7.2 SUMMA Canister Sample Collection

The following equipment must be available and operational to perform sampling with SUMMA canisters:

- 1) Pump(s) must be charged, in good working order, and set with the appropriate flow rate of 3 liters per minute
- 2) SUMMA canisters must be certified clean.
- 3) Sample documentation (sample labels, field data sheets, logbook, chain of custody records, custody seals, etc.)
- 4) Air sampling worksheets
- 5) PID or other field air monitoring devices

7.3 Field Measurement of VOCs with PID (or other field instrument)

The following equipment must be available and operational to perform Field Testing of VOCs with a PID:

- 1) PID instrument, user's manual, calibration gas and regulator, zero gas, or virgin charcoal tubing). The PID must be fully charged the night before (and include spare batteries if feasible).
- 2) Tedlar bags must be new.
- 3) Sample documentation (sample labels, field data sheets, logbook, chain of custody records, etc.).
- 4) Air sampling worksheets
- 5) Opaque trash bags
- 6) Any other equipment defined in section 6.1

8.0 REAGENTS

- 1) Calibration gases, typically isobutylene at 10 ppm for a Rae ppb PID or 100 ppm for other PIDs.
- 2) Materials required to zero the PID instrument (sealed virgin charcoal tubes for the Rae ppb PID or Ultra-zero grade compressed air for other PIDs).

9.0 PROCEDURES

9.1 Flushing the Volume of the Sampling Train

The sampling train will contain a volume of ambient air that must be flushed from the system before the sample is collected. The flushing volume may be determined by a volume calculation and/or by using a field instrument to verify that the initial volume has been purged. Teflon tubing (not Tygon tubing) should be used for the sampling train. Typically three volume flushes should be sufficient for removing ambient air from the sampling train. During the flushing process, air will be released to the atmosphere in a downwind direction.

9.2 Sample Collection with Tedlar Bag

- 1) Follow Section 9.1, to evacuate the volume of the sampling train. If PID/FID readings were taken prior to taking a sample, additional evacuation is not necessary.
- 2) Use the vacuum box and sampling train (Figure 1) to collect the sample. The sampling train must be designed to minimize the introduction or loss of contaminants due to adsorption and other factors. All parts used are either Teflon or stainless steel, and a vacuum is drawn indirectly to avoid contamination from sample pumps.
- 3) Place the Tedlar bag inside the vacuum box, attach it to the sampling port and open the valve. The sample probe is attached to the sampling port via Teflon tubing and a "Quick Connect" fitting.
- 4) Draw a vacuum around the outside of the bag, using a pump connected to the vacuum box evacuation port, via Tygon tubing and a "Quick Connect" fitting. The negative pressure inside the box causes the bag to inflate, drawing the sample into the bag.
- 5) Break the vacuum by removing the Tygon line from the pump. Remove the bagged sample from the box and close the valve. Record the date, time, sample location identification, and the PID instrument reading (if used) on the sample bag's label, and on the appropriate data sheet or in the site logbook(s). Bags should not be labeled directly with a marker or pen (particularly those containing volatile solvents) or should adhesive labels be affixed directly to the bags. Inks and adhesive may diffuse through the bag material and contaminate the sample. Labels should be tied to the metal eyelets provided on the bags.
- 6) Complete chain of custody records.

This sampling approach (Tedlar bag sampling) is straightforward and relatively easy. However, there are several things to be aware of when sampling.

- 1) The seals of the vacuum box must be air tight in order for the sample collection system to work.
- 2) Check the O-ring gasket to see if it is in place with the proper fit. O-rings that have been stretched out will not remain in place, thus requiring constant realignment.
- 3) Check that all the fittings associated with the vacuum joints are securely in place. The fittings can be pushed loose when inserting the valve stem into the Teflon tubing.
- 4) Occasionally, a corner of the Tedlar bag will stick out between the two halves of the vacuum box causing a poor seal.
- 5) Since the Tedlar bags will only hold a finite volume (e.g. - liter Tedlar bag), over-inflation will burst the bag.

9.3 Sample Collection with SUMMA Canister

- 1) Follow Section 9.1, to evacuate the volume of the sampling train. If PID/FID readings were taken prior to taking a sample, additional evacuation is not necessary.
- 2) Attach a certified clean, evacuated 6-L SUMMA canister via the ¼" Teflon tubing.
- 3) Open the valve on the SUMMA canister. The vapor sample is drawn into the canister by pressure equilibration.
- 4) Record the date, time, sample location identification, and the PID instrument reading (if used) on the sample label (use ball point pen only), and on the appropriate data sheet or in the site logbook(s).
- 5) Complete chain of custody records.

9.4 Remediation System Sampling

The sampling procedure to be used for a remediation system depends upon the sampling point.

- 1) If the sampling point is under vacuum (such as a sampling port at the well head on an SVE system); follow the sample collection procedure defined in Sections 9.2 or 9.3.
- 2) If the sampling point is under pressure (such as the discharge side of a blower for a SVE system); use the following procedure:
 - a) Attach a piece of Teflon tubing to the sampling port.
 - b) Open the valve on the sampling port.
 - c) Flush the tubing in the line for an appropriate number of volumes. During the flushing process, air will be released to the atmosphere in a downwind direction.
 - d) Connect Tedlar bag (or SUMMA canister) to the Teflon tubing and fill via the line pressure.
 - e) Remove sample from the tubing. Record the date, time, sample location identification, and the PID instrument reading (if used) on the sample bag's label, and on the appropriate data sheet or in the site logbook(s). Bags should not be labeled directly with a marker or pen (particularly those containing volatile solvents) nor should adhesive labels be affixed directly to the bags. Inks and adhesive may diffuse through the bag material and contaminate the sample. Labels should be tied to the metal eyelets provided on the bags.
 - f) Complete chain of custody records.

9.5 Field Measurement of Organic Vapor Levels with PID

The manufacturers' manual must be consulted for the correct use and calibration of all instruments. Pumps should be calibrated prior to use in the field.

- 1) Collect a sample following the procedures defined in Sections 8.2 or 8.4.
- 2) Connect the PID probe to the sample container using a section of Teflon tubing
- 3) Use the PID to read the organic vapor level present in the sample.
- 4) Record the date, time, sample location identification, and the PID instrument reading on the appropriate data sheet or in the site logbook(s).
- 5) Repeat the sample collection and PID reading from the same sampling point to verify repeatability (the same Tedlar bag may be reused on this same sampling point for this repeat sampling).

- 6) Retest the instrument calibration after 4 hours of operation and at the end of day.

Readings may be above or below the range set on the field instrument. The range may be reset, or the response recorded as a greater than or less than the response range.

10.0 CALCULATIONS

10.1 Field Screening Instruments

Instrument readings are usually read directly from the meter. For example, PID readings are expressed in units of parts per million (ppmv) or part per billion (ppbv) depending on the PID unit. In some cases, it may be appropriate to subtract the background reading from the sample reading.

10.2 Correction Factors

A PID instrument will (typically) be calibrated to isobutylene as a calibration gas. Therefore a correction factor must be used when converting the PID response to the actual VOC concentration present in the sample. Using a PID, the instrument responds to the total organic vapors present in sample and conversion to a specific VOC concentration may be made when a specific compound present is known (based on prior sampling or other site operational knowledge). Typical PID correction factors for several for the common VOCs encountered are shown in Table 1. Appendix B includes a copy of Technical Note TN-106 from Rae Systems which presents a list of chemical compounds and their PID response correction factors (from conversion from isobutylene calibrated response to VOC concentration).

Table 1 Ionization Potential and Correction Factors for Common Compounds

Compound	Ionization Potential (eV)	Correction factor for response relative to isobutylene calibration (for 10.6 v lamp)
Acetone	9.71	1.1
Methyl ethyl ketone	9.51	0.5
Benzene	9.25	0.53
Ethylbenzene	8.77	0.52
Toluene	8.82	0.50
o-Xylene	8.56	0.59
Tetrachloroethene	9.32	0.57
Trichloroethene	9.47	0.54
Vinyl chloride	9.99	2.0
cis 1-2 dichloroethene	9.66	0.8
Isobutylene	9.24	1.0

10.3 Unit Conversions

Two common units are used to express vapor phase concentrations:

- mass per unit volume basis (e.g., $\mu\text{g}/\text{m}^3$ and $\mu\text{g}/\text{L}$); and
- volume/volume basis (ppbv, ppmv).

Field instrument readings (read directly from the meter) are typically on a volume/volume basis. Laboratory results may be presented in either units (or both).

The conversion between units is as follows:

$$1 \text{ ug/m}^3 = [(273.3+T)*0.082/MW] \text{ ppbv}$$

Where T is temperature in degrees C and MW is molecular weight.

11.0 QUALITY ASSURANCE/QUALITY CONTROL

11.1 Sample Probe Contamination

Sample probe contamination is checked between each sample by drawing ambient air through the probe using a vacuum pump (e.g., Gilian pump) and checking the response of the PID. If readings are higher than background, replacement or decontamination is necessary. Sample probes may be decontaminated simply by drawing ambient air through the probe until the PID reading is at background. Contamination can also be removed by decontaminating with methanol and deionized water, then air drying. For persistent contamination, use of a portable propane torch may be needed. Using a pair of pliers to hold the probe, run the torch up and down the length of the sample probe for approximately one to two minutes. Having multiple probes per sample team will reduce lag times between sample stations while probes are decontaminated.

11.2 Sample Train Contamination

The Teflon line forming the sample train from the probe to the Tedlar bag should be changed on a daily basis. If visible contamination (soil or water) is drawn into the sampling train, it must be changed immediately. When sampling in highly contaminated areas, the sampling train should be purged with ambient air, via a vacuum pump (e.g, Gilian pump), for approximately 30 seconds between each sample. After purging, the sampling train can be checked using a PID, or other field monitoring device, to establish the cleanliness of the Teflon line.

11.3 PID Calibration and Testing

- 1) All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan.
- 2) Equipment checkout and calibration activities must occur prior to sampling/operation, they must be documented.
- 3) All data must be documented on field data sheets and/or within site logbooks.

11.4 Trip Blanks, Field Blanks, Duplicates, Lot Blanks

The project QA plan needs to define the appropriate level of trip blanks, field blanks, duplicates, and lot blanks to meet the sampling objectives. Typical examples that should be considered in the QA plan development include;

- A trip blank or field blank to detect any sample contamination during shipping and storage.
- A trip standard used to determine any changes in concentrations of the target compounds during the course of the sampling day (e.g., migration through the sample bag, sample degradation, or adsorption to the bag's surface).

- A lot test sample from each lot of Tedlar bags to be used for sampling and checked for possible contamination (filled with ultra-zero grade air) and analyzed.
- A lot test of cleaned SUMMA canisters used for a GC/MS certification check. If the canister passes certification, it is re-evacuated and all canisters from that lot are available for sampling. If the chosen canister is contaminated, the entire lot of SUMMA canisters must be re-cleaned, and a single canister re-analyzed by GC/MS for certification.

12.0 DATA VALIDATION

If the same profile or pattern of VOCs found in the samples is observed in the blanks, the collection method and storage procedures must be evaluated. Depending on the levels observed, the data may be qualified as estimated or not usable (not valid).

13.0 REFERENCES

Gilian Instrument Corp. 1983. Instruction Manual for Hi Flow Sampler: HFS113, HFS 113 T, HFS 113U HFS 113 UT.

International Air Transport Association Dangerous Goods Regulations

New Jersey Department of Environmental Protection. 1992. Field Sampling Procedures Manual.

Rae Systems, Parts per Billion VOC Monitor PGM-7240 Operation and Maintenance Manual

U.S. Environmental Protection Agency. 1984. Characterization of Hazardous Waste Sites - A Methods Manual: Volume II. Available Sampling Methods. 2nd ed. EPA-600/4-84-076.

U.S. Environmental Protection Agency. 1995. Superfund Program Representative Sampling Guidance. Volume 2: Air (Short-Term Monitoring). EPA 540-R-95/140.

14.0 APPENDICES

Appendix A - Parts per Billion VOC Monitor PGM-7240 Operation and Maintenance Manual

Appendix B – Correction Factors, Ionization Energies, and Calibration Characteristics

WELL CONSTRUCTION AND DEVELOPMENT CALIBRE STANDARD OPERATING PROCEDURES

1.0 POLICY

It is the policy of CALIBRE that any individual engaging in well construction and development at job sites will abide by the procedures outlined in this document. These procedures are designed to meet or exceed guidelines set forth by the Washington Administrative Code (WAC 173-160) or other state agency for monitoring well construction and development.

2.0 PURPOSE

This Standard Operating Procedure (SOP) provides instructions that are to be followed in construction and development of wells.

3.0 WELL CONSTRUCTION MATERIALS

The following materials will be used in the construction of groundwater monitoring wells, soil vapor extraction wells, enhanced reductive dechlorination injection wells, and dual phase extraction wells.

- 2, 4, or 6-inch I.D. schedule 40 PVC flush threaded blank casing
- 2, 4, or 6-inch I.D. schedule 40 PVC slotted casing (screen) of appropriate slot size
- 2, 4, or 6-inch I.D. schedule 40 PVC threaded and slip caps
- Stainless steel well centralizers
- Mild steel protective casing of appropriate diameter
- Locking standpipe cap
- Traffic-rated watertight flush mount well housing enclosure
- Steel bollards
- Locking compression plugs or seals
- Shale trap
- Combination or key lock
- Filter pack sand
- Type I or II Portland cement
- Concrete
- Bentonite powder, pellets, or chips

4.0 WELL DEVELOPMENT EQUIPMENT

The following materials and equipment are needed for development of wells:

- 2, 4, or 6-inch surge block
- Appropriate high volume pump (centrifugal, submersible, etc.)
- DOT approved 55-gallon drums
- Teflon, PVC, or stainless steel bailer with cord or cable

5.0 WELL CONSTRUCTION PROCEDURES

The following steps describe the typical procedure for construction of a groundwater well:

- 1) All wells are to be constructed in accordance with the regulations of the state in which they are constructed and with ASTM Procedure D-5092.
- 2) A monitoring well consists of a PVC Schedule 40 well casing, slotted screen, threaded or slip bottom cap, and compression plug. Following completion of the boring, install the monitoring well through the center of the hollow stem auger, drive casing, or open boring. The casing string must be centered in the borehole and held in tension during installation. Other types of wells are similar with additional components as shown on the design diagrams.
- 3) Place clean, well graded silica sand around the well screen to serve as the filter pack. The grade of the sand is chosen on the basis of the aquifer units encountered. The filter pack is emplaced as the auger or temporary casing is withdrawn from the boring. Caution must be taken to prevent the sand from bridging when it is being emplaced. The filter pack must extend a little above the top of the screen.
- 4) Place a 2-foot to 3-foot thick pellet or chipped bentonite seal above the sand pack as the auger or casing is withdrawn. Bentonite seals should not be placed in the vadose zone as they will desiccate, losing their ability to seal. If the screen extends into the vadose zone, use a tremie pipe to slurry in Portland cement for the seal.
- 5) Fill the remainder of the annulus between the well casing and the borehole with cement/bentonite grout (approximately 5% bentonite) or a high-solids bentonite slurry (11 – 13 pounds per gallon) to the approximate depth of frost penetration, or no higher than one foot below ground surface. If the water level is higher than the seal, use a tremie pipe to place the grout. At depths greater than 15 feet, use of a tremie pipe is advisable.
- 6) Install either a threaded cap or a locking watertight compression seal on the monitoring well.
- 7) Place a protective steel casing with locking cap over the well casing set in concrete to a depth approximately equal to frost penetration or at least two feet below ground surface. In traffic areas, place a traffic-rated flush mount enclosure over the well set in concrete. The top of the flush mount should be approximately one inch above grade to prevent runoff from entering the well. A concrete apron should be constructed to grade down to the existing asphalt or concrete surface.
- 8) For above ground completions, ensure that the well casing extends two to three feet above ground and is surrounded by traffic bollards set three feet deep in concrete.

6.0 WELL DEVELOPMENT PROCEDURES

The following steps describe the typical procedure for construction of a groundwater well:

- 1) Prior to development, measure the depth in each well to static water level and total casing depth to a mark on the top of the well casing. Well development should not commence until 24 hours after completion of well construction to allow for grout and concrete to cure.

- 2) Each well development cycle consists of surging and pumping. Surging should consist of a minimum of ten surges with an appropriately sized surge block over the full length of the screen. In the case where the screen extends to above the water table, water may have to be added to the well to develop the top of the filter pack.
- 3) After surging, water is pumped out of the well until the pumped stream starts to clear. At that point, stop pumping and initiate another surge cycle. When the pumped water clears substantially in less than a minute, the well may be deemed to be developed. Perform a minimum of three surge and pump cycles.
- 4) Surging should not be performed on wells completed in fine-grained materials due to the potential for formation erosion.
- 5) During development of each well and at the completion of development, record the following field parameters and observations:
 - Depth to water
 - Development time and volume
 - Development flow rate
 - Other observations (color, odors, sheen)

7.0 WELL CONSTRUCTION AND DEVELOPMENT WASTE

Place all drill cuttings and development water in appropriately labeled DOT approved drums for characterization and proper disposal by client.

WELL DRILLING, CONSTRUCTION, AND SAMPLING IN ROADWAYS CALIBRE STANDARD OPERATING PROCEDURES

1.0 POLICY

It is the policy of CALIBRE that any individual conducting work on any roadway at jobsites will abide by the procedures outlined in this document. These procedures are designed to meet or exceed applicable OSHA standards for safe work practices.

2.0 PURPOSE

This standard operating procedure (SOP) provides instructions that are to be followed in drilling, construction, and sampling of wells in the roadways. The activities and requirements listed in this SOP are designed to ensure that work in roadways is accomplished in a safe manner and follows all municipal or other regulations and codes.

3.0 PERMIT

Before any work can be done in roadways or on sidewalks at CALIBRE job sites, a permit must be acquired from the city Public Works department and/or other appropriate agency. All rules and requirements listed on the permit or permits must be followed.

For example, permit contact information for the MSLC site in Modesto, CA is as follows:

Wendy Correia
Public Works Department
1010 Tenth Street
Modesto, CA 95353

Samira Marei
Caltrans, District 10
908 N. Emerald Avenue
Modesto, CA 95351

4.0 PRESAMPLING ACTIVITIES

Local police and/or local permit inspector should be notified of the time and location of the road closure/work.

Before drilling or sampling, the road lane with the wells must be closed with a barricade and a “Road Closed” sign. The area where the work will be accomplished must be cordoned off with fluorescent orange traffic cones. Placement and spacing should be in accordance with permit requirements. A flagger with a “stop/slow” paddle will direct traffic away from the job site activities.

5.0 ACTIVITIES DURING DRILLING, CONSTRUCTION, AND SAMPLING

Work activities in the roadway should be performed only during daylight hours unless special circumstances dictate otherwise. Additionally, work must be performed on Saturdays or Sundays or after 1800 hours on weekdays when daylight conditions allow in areas of high traffic.

Orange or other brightly colored safety vests should be worn by all personnel on site. During activities in the roadway, one person must observe and control traffic using a “stop/slow” paddle.

Barricade and traffic cones must be removed after activities in the roadway have been completed, well vault covers replaced and secured, and all equipment removed from the roadway.

UTILITY CLEARANCE REQUIRED PRIOR TO INTRUSIVE INVESTIGATION OR REMEDIAION ACTIVITIES CALIBRE STANDARD OPERATING PROCEDURES

1.0 POLICY

It is the policy of CALIBRE that any individual engaging in any intrusive investigation or remediation work (well/test boring, drilling, direct push sampling, test pit excavations or similar subsurface investigation work) at job sites will abide by the procedures outlined in this document. These procedures are designed to meet or exceed guidelines set forth by the Washington Utilities Coordinating Council (WUCC) or other similar agencies in different states.

2.0 PURPOSE

This Standard Operating Procedure (SOP) provides instructions that are to be followed for utility clearance prior to starting intrusive investigation or remediation work. Underground utility clearance (gas, water, sewer, power, communication, other) is an initial step prior to any intrusive/drilling work, all steps must be completed and documented.

3.0 STEPS FOR UTILITY CLEARANCE

Subsurface utility drawings must be requested from the client/property owner or other appropriate entity. Personnel will conduct a field inspection of the site and review available subsurface utility drawings. The field inspection must look for obvious (or potential) signs of utilities such as alignment of storm drains, location of utility meters, power lines connecting down from power poles, power lines connecting up to service connections, or saw cuts in the surface cover. Field locations will then be marked on the ground and on a suitable base map that can be provided to other parties. Detailed information on the locations must be recorded (map page from Thomas Guide, cross streets that are nearby, and distance from easily identified reference locations such as corner of a specific building).

Prior to the installation of any new wells a utility clearance will be performed and the utility clearance SOP reviewed. The utility clearance will be performed using the following steps:

- 1) Review available as-built drawings of utility locations,
- 2) Complete any client-specific review/permitting required (dig permits or other),
- 3) Call the Utility Notification Center (UNC) at least 48 hours prior to drilling,
- 4) Engage third party utility survey/clearance in moderate or high risk areas, and
- 5) If necessary, hand dig the first 2-5 feet.

3.1 COMPLETE ANY CLIENT-SPECIFIC UTILITY CLEARANCE PROCESSES

Various customers/clients may have existing processes in place for utility clearance on their property (such as dig permits or other). The project Work Plan needs to determine any client-specific (or locality-specific) processes/documentation required and the required steps followed and documented. The client-specific requirements may overlap with the subsequent steps listed below, however both are required if they do not overlap.

3.2 CONTACT UTILITY NOTIFICATION CENTER

The Utility Notification Center (UNC) will be notified at least 48 hours, during working days, prior to initiation of subsurface investigation or remediation so that subscribers can mark their nearby utilities. The call will be documented (time, date and reference number provided). Any return information provided will be documented (typically a return phone call from various utility providers that local utilities have been marked and that specific utilities are present or not present in the area).

3.3 INDEPENDENT UTILITY SURVEY

Many project locations are on private property where limited (if any) clearance is provided by the UNC service. As appropriate based on the UNC information, as-built drawings and the general nature of development in the area, CALIBRE will retain an independent utility locator to assess the potential presence of subsurface utilities and structures in the area (beyond the as-built utility review and UNC clearance noted above). Subsurface anomalies detected during the utility survey will be marked with paint and/or flagging. The area around each location will be cleared to a minimum of 5 feet from the marked location to allow for alternate locations in case of refusal during drilling at the primary location.

3.4 MANUAL CLEARANCE IN CONGESTED AREAS

If the area indicates many nearby utilities, a manual clearance of utilities (visual inspection within the hole) must be completed. Two options (potentially more) exist for this: manually dig down with a post-hole digger or contract with a vacuum truck equipped with an air knife to clear each boring location. In most soils a post-hole digger can be used to clear to a depth of 3 to 4 feet. A vacuum truck with an air knife can clear to an approximate depth of 6- to 8-feet (potentially deeper). If a subsurface utility or other obstruction is encountered, the boring locations will be adjusted as necessary.

4.0 DOCUMENTATION

All steps noted above are to be documented in site logbooks and retained in the project files.

ATTACHMENT B
HEALTH AND SAFETY PLAN

HEALTH AND SAFETY PLAN

**20th Street and Factor Avenue
Yuma, Arizona**

**Water Quality Assurance Revolving Fund Site
Arizona Superfund Response Action Contract**

Contract Number: ADEQ14-077538

Prepared for:

Matrix-CALIBRE Team Site Work at the 20th Street and Factor Avenue Site

Under Task Order ADEQ14-077538:17

from

Arizona Department of Environmental Quality

1110 W Washington Street

Phoenix, AZ 85007

Prepared by:



January 15, 2016

Rev 0

Revision History

Name	Date	Reason for Changes	Version
Tom McKeon (TM)	15- Jan 16	Initial draft	1.0 Draft 0

EMERGENCY CONTACTS LIST

911 is available in this area for medical, police, or fire emergencies.	
Hospital:	Northside Medical Clinic 1394 W 16th St, Yuma, AZ 85364
Telephone #:	(928) 539-0055
Facility Address:	655 E. 20th Street Yuma, Arizona (Houston LLC Facility)
Fire, Police, Ambulance	911
Poison Center Telephone #:	(800) 732-6985
National Response Center (NRC) Telephone #:	(800) 424-8802
ADEQ Emergency Response Unit (ERU)	Spill reporting (602) 771-2330 or 234-5677 Emergency (602) 390-7894
ADEQ Project Manager	Kevin Snyder (602) 771-4186
CALIBRE Project Manager	Tom McKeon (425) 241-8449
CALIBRE Site Health and Safety Officer	Justin Neste (360) 981-5606
CALIBRE Health and Safety Program Manager	John Frerich (425) 226-6435 Cell (425) 227-8305 Home

ACRONYMS AND ABBREVIATIONS

µg/L	Microgram per liter
1,1-DCE	1,1-Dichloroethene
CALIBRE	CALIBRE Systems, Inc.
CFR	Code of Federal Regulations
COC	Contaminant of Concern
CPR	Cardiopulmonary Resuscitation
DCE	Cis-1,2-dichloroethene
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HI	Heat Index
IDW	Investigation derived waste
Matrix	Matrix Design Group, Inc.
MCL	Maximum concentration limit
MSDS	Material safety data sheet
NIOSH	National Institute for Occupational Safety and Health
OPIM	Other potentially infectious materials
OSHA	Occupational Safety and Health Administration
PCE	Tetrachloroethylene
PDB	Passive diffusion bags
PEL	Permissible exposure limit
PPE	Personal protective equipment
SAP	Sampling and Analysis Plan
Site	20th Street and Factor Avenue
SSHO	Site Safety/Health Officer
TCE	Trichloroethylene
UV	Ultraviolet
VC	Vinyl chloride
VOC	Volatile organic compound

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FIGURES

FIGURE 1: General Site Location Map

FIGURE 2: Monitoring Well Location Map

FIGURE 3: NOAA Heat Index Chart

FIGURE 4: Hospital route from Site Northside Medical Clinic

ATTACHMENTS

ATTACHMENT A: MSDS/NIOSH CARDS

ATTACHMENT B: JOB HAZARD ANALYSIS

ATTACHMENT C: TAILGATE PRE-FIELD BRIEFING AND SAFETY PLAN REVIEW

1.0 PURPOSE

This Health and Safety Plan (HASP) establishes the basic safety guidelines and requirements to conduct field sampling to complete the scope of work for the 20th Street and Factor Avenue WQARF Site (Site) in Yuma, AZ. The work described in this HASP is being conducted by CALIBRE staff under contract to the Matrix Design Group (Matrix), which is under contract to the Arizona Department of Environmental Quality (ADEQ). This HASP addresses potential hazards that may be encountered during well drilling, groundwater, soil, or vapor sampling that may be completed at the Site. This plan has been prepared in accordance with CALIBRE Systems, Inc.'s (CALIBRE) Corporate Health and Safety Program Plan¹.

The protection of employees and the public is the first concern during all activities at the Site. Health and safety concerns that require evaluation and mitigation include risks associated with well drilling, groundwater monitoring, remedial operations, physical hazards, chemical hazards, and motor vehicle traffic at the Site.

This HASP provides key hazards communication information to employees related to this project. More general health and safety information is transmitted to employees by a variety of methods, including letters and memos, and direct communication. The Matrix-CALIBRE Safety Manager will make general health and safety related information available to all staff via posting on workplace bulletin boards and/or information systems. In addition, health and safety issues are discussed at meetings. All employees are encouraged to contact the Matrix-CALIBRE Safety Manager at any time to discuss hazards that are identified in the work place.

The provisions set forth in this HASP will apply to Matrix-CALIBRE employees and any subcontractors working for Matrix-CALIBRE at the Site. All personnel working for the Matrix-CALIBRE at the job site must read and understand this HASP, and sign the attached Compliance Agreement before entering the work area or beginning the work. All Subcontractors will be required to follow an appropriate HASP (preferable their own) including all elements of this HASP; or they will be provided a copy of this HASP (prepared by Matrix-CALIBRE) that they must follow.

2.0 SITE DESCRIPTION AND PROJECT SCOPE

2.1 Site Description

The Site is located in Yuma, Arizona (Figure 1). The primary source is the former Houston Photo Products Facility (Facility) located at the southeast corner of the intersection of 20th Street and Factor Ave in Yuma, AZ. The plume footprint in groundwater extends to the northwest about 4,100 ft. The Site includes a mixture of commercial and light industrial businesses, warehouses, residential neighborhoods, and two schools encompassing an area of approximately 80 acres. Releases of volatile organic compounds (VOCs) and cyanide are documented at Facility. To date, no other sources of VOCs and cyanide have been identified from other potential sources in the area. The contaminant plume (as presented in the 2014 Remedial Investigation) extends approximately 4,100 feet to the northwest down-gradient from the source and is roughly bounded by 17th Street to the north, 21st Street to the south, 3rd Avenue to the west, and Kennedy Lane to the east (Figure 1). Floating petroleum hydrocarbon free product has been intermittently observed in several wells on the north side of 20th Street from the site, which is probably related to a diesel release from a Union Pacific Yuma Yard facility, also known as the Dieselveille site.

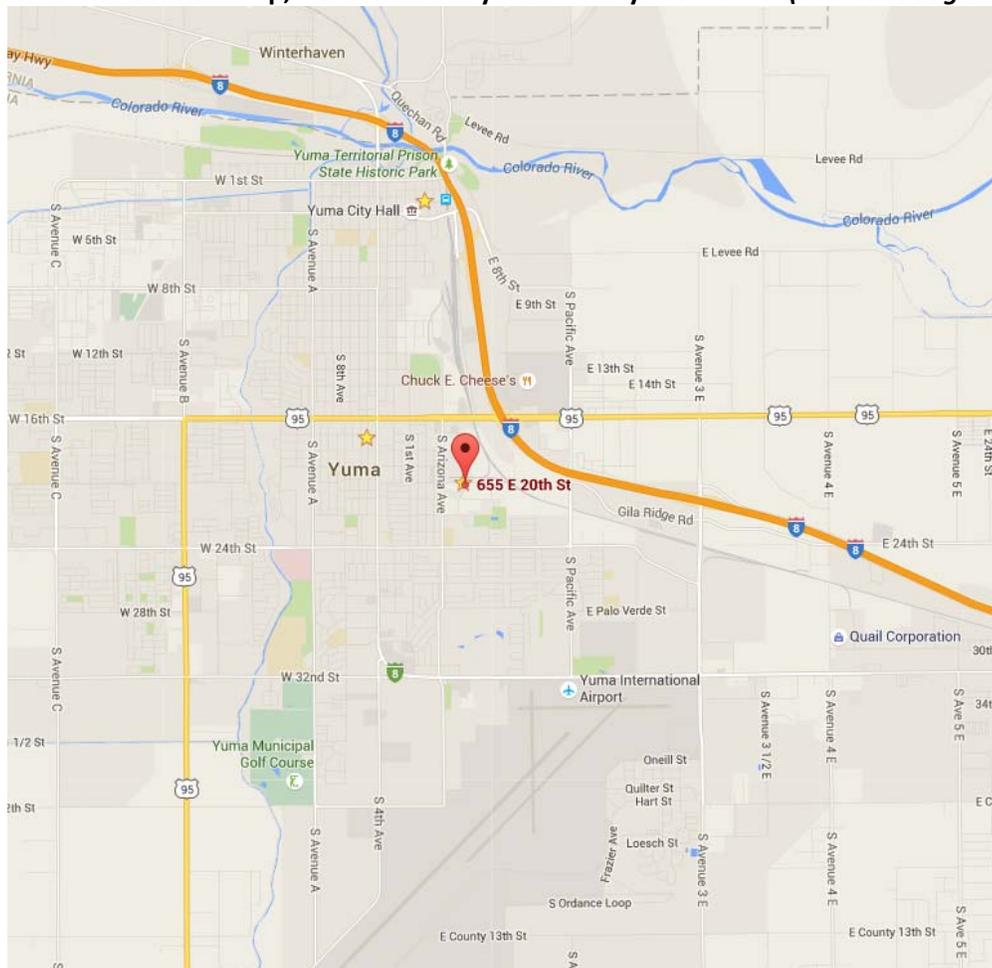
Tetrachloroethene (PCE) is the primary contaminant of concern (COC) identified at the Site; other COCs identified in the 2014 Remedial Investigation (RI) include trichloroethene (TCE) and 1,1-dichloroethene (DCE)

¹ CALIBRE 2006. CALIBRE Corporate Health and Safety Program Plan

and cyanide. The COCs have been detected in soil, soil vapor, and groundwater. Based on the areal extent of COCs above the Aquifer Water Quality Standards (AWQSS), groundwater is the most significantly impacted environmental media. There is also a substantial vapor plume of VOCs but the concentrations are not anticipated to represent a significant risk. The extent of the VOC plume in groundwater covers approximately 65 acres (Tetra Tech, 2014). There are no municipal groundwater users known at the Site. Private groundwater use includes the two downgradient schools Alice Byrne Elementary School (located approximately 5,500 ft down gradient of the source area) St. Francis of Assisi School (located approximately 4,800 ft down gradient of the source area), and a nearby private well located up gradient of the Facility.

The soil vapor plume extends approximately 2,400 feet down-gradient from the source area. The vapor plume is aligned with the groundwater plume and extends from the ground surface to the water table (approximately 80 ft below ground surface [bgs]). The most recent soil vapor VOC concentrations are highest near the Facility at 60 ft bgs (15,000- 20,000 microgram per cubic meter [$\mu\text{g}/\text{m}^3$] PCE). Hydrogen cyanide had been detected in soil vapor beneath the Facility in 2003 and 2004. However, more recent data collected in 2010 and 2011 did not show hydrogen cyanide detections in soil vapor. Analysis for hydrogen cyanide was included in selected locations for the most recent (2014) offsite soil vapor survey and all soil vapor samples for hydrogen cyanide were below detection limits.

Figure 1: General Site Location Map, Houston Facility is shown by the marker (Source: Google Maps, 2015)



2.2 Project Scope

The scope of work for this project will include well installation and groundwater monitoring at the Site (see Figure 2). Other environmental investigation/remediation work could potentially include vapor sampling, minor construction, direct-push borings and sampling. Groundwater samples may be collected using passive diffusion bags (PDBs), low flow sampling, and grab samples (HydraSleeve).

3.0 CLIMATE

The Site is located within the Sonoran Desert Climate Region characterized by hot summers and mild winters. The average summer high temperatures for most days from late May through early October exceeds 100°F (43 °C). Precipitation is sparse during most of the year. Extreme heat in summer months is an important safety hazard on this project. During the monsoon season (June to September) rainfall can occur that is very heavy and may cause localized flooding of streets. Additionally, monsoons are often accompanied by lightning; which pose safety hazards personnel should be aware of.

4.0 JOB HAZARD ANALYSIS/SITE CHARACTERIZATION

This section addresses the physical, chemical, biological and weather related hazards that may be encountered during performance of the scope of work and the precautions that need to be taken (also see Attachment B for Job Hazard Analysis Sheet).

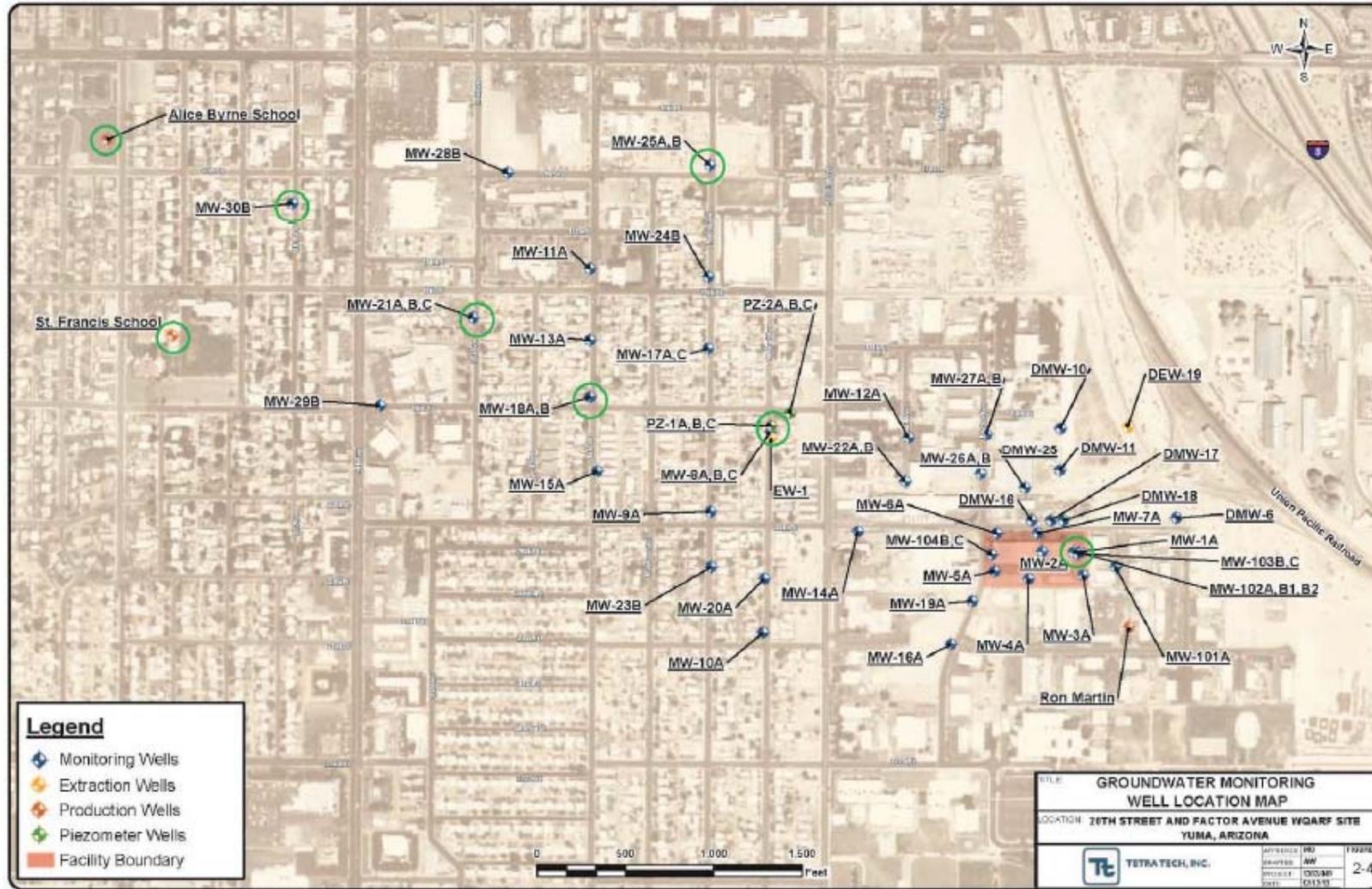
4.1 Physical Hazards

There is potential for physical hazards at the Site associated with the expected field work of groundwater monitoring, to include well drilling and construction. When working with equipment it is the operator's responsibility to follow company safety procedures, all procedures and safety considerations presented in this site specific HASP. All operations personnel must be thoroughly familiar with all equipment including all emergency shutdown procedures, spill response, and notification procedures.

Field work will be conducted with an appropriate number of staff for the tasks to be completed. The specific hazards expected at the job site (and steps that will be taken to mitigate/manage those hazards) include:

- Mobilization/Demobilization: Personnel will have a valid driver's license, use defensive driving techniques and will yield to all pedestrians and other vehicles. Crews will use a spotter when backing up.
- Slip, trip and fall hazards: Personnel will wear proper footwear to prevent slipping (if wet surfaces are encountered) and other foot related injuries (steel-toe, traction soles, etc.). During preparation of the Site work area, specific slip, trip and/or fall hazards will be identified and clearly marked, or removed. If specific work areas represent unusual physical hazards (slip, trip and fall hazards) field staff will notify the project manager an alternate access points arranged and/or increased safety equipment provided.
- Electrical shock: Personnel will be trained in the operation of any electrical equipment to be used, and maintain safe working practices when working around or handling electrical equipment (generators, electrical cords, etc.). Extreme caution will be employed during electrical/lightning storms. If a lightning storm occurs during SVE maintenance, personnel will retreat a safe distance from electrical equipment and power lines until the storm has passed.

Figure 2: Monitoring Well Location Map (Source: Tetra Tech, 2014)



- Precautions for working in a parking lot/roadway: Personnel will maintain a safety zone around the immediate work site in areas where pedestrian and/or motor vehicle traffic is expected. Work zone delineation will be accomplished with orange traffic cones, caution tape and/or traffic barriers. All personnel will wear high-visibility safety vests (or other equivalent).
- Pinch points, cuts or punctures: Personnel will exercise caution while working around sharp objects. Personnel will wear appropriate work gloves (e.g., leather or other) while handling equipment/tools/materials.
- Eye injuries: Personnel will wear approved safety glasses when performing work tasks that pose the potential for an eye injury. If appropriate, a full face shield will be used when/if required.
- Noise: Hearing protection will be used if equipment generating noise exceeds 85 dBs (decibels).

4.1.1 Well Construction and Direct-Push Hazards

If project scope requires it, well drilling, construction, and direct-push borings will be performed by a drilling subcontractor licensed to perform such work in the State of Arizona. Hazards common to well drilling/construction and direct-push sampling are included in Table 1. All utilities (power, sewer, etc.) must be cleared before any drilling, or direct-push boring will be performed. Drilling and boring operations will require area controls in the vicinity of the drill rig to keep non-essential personnel at a safe distance (traffic cones and flagging). Personnel must wear high visibility vests and hard hats when around drilling equipment. Heavy equipment may cause excessive noise and personnel are required to wear proper PPE.

Table 1. Hazards Summary Associated with Site work and Well Drilling

Site Preparation Hazards	Electrical and telephone utility installation
	Placement of temporary project support facilities
Well Construction and Direct-Push Hazards	Overhead hazards from drill rig
	Mechanical hazards of drilling and excavation
	Slope/cave-in hazards of excavation
	VOCs exposure hazard when drilling or sampling (vapor or water)
	Underground and overhead utilities
Facility Installation Hazards	Mobilization/setup of the mechanical systems trailer
	Pressure and vacuum hazards of air and vacuum lines
System Operation Hazards	VOCs in off gas
	Pressure and vacuum in air supply lines
	High voltage in power supply systems
	High pressure gas bottles
Chemical Exposure Hazards	Acid used as pH control in sample preservation and/or injected into
	VOCs in water and air
Slip, Trip and Fall Hazards	Slippery surfaces
	Surface pipes/hoses as tripping hazards
	Falling from ladders, steps or elevated platforms
Weather Related/Heat Stress Hazards	Dehydration due to loss of fluids
	Heat illness/ Stress
	Working in impermeable clothing
	Hypothermia from exposure in cold conditions
	Dangerous weather conditions (electrical storms, ice)

4.1.2 Remedial System Installation Hazards

Remedial system installation, such as a SVE system, will require the placement of equipment and electrical service. Equipment may include, but is not limited to, blowers, motors, air transport piping, and programmable logic control (PLC) panels. This activity may require the placement and leveling of a fully contained equipment trailer or equipment skid. Air and vacuum lines from the wells to the system will be placed at the ground surface or below ground surface if lines are located in a vehicle traffic area. Electrical connections must be completed between the system and the utility service line. Electrical connections from the power drop to the equipment system must be made by a licensed electrician. Additional electrical wiring may be required to connect system monitoring devices to the control panels. Above-ground facility installation hazards are included in Table 1.

4.1.3 Remedial System Start-up, Operation and Maintenance Hazards

System start-up will involve testing the operation of mechanical systems and testing all air and vacuum distribution lines for tightness and function. When all of the mechanical systems are confirmed to be

operational, the final connections will be made at the well head and the system started. The system will be monitored regularly during the initial startup period. During this time the operators will observe the function of all systems and confirm proper system operation.

Operation and maintenance of the system may include routine service of the blower system per manufacturer's recommendations. The equipment system will need to be shut down in order to perform some of the required O&M activities (e.g., oil changes, belt tensioning/replacement, other miscellaneous items). The system must also be shut down before removing any safety features (belt guards, etc.) to access belts or oil changing points. The vapor treatment system will require routine service and maintenance based on the type of treatment technology installed (e.g., granular activated carbon). During operation and maintenance activities, personnel must be aware that the air stream and treatment system (particularly sorptive systems, such as granular activated carbon) may contain relatively high concentrations of the contaminants of concern (e.g., volatile organic compounds, such as PCE, TCE, DCE, and VC). These compounds are toxic and precautions will be necessary to minimize employee exposures to them (e.g., nitrile gloves, safety glasses, dust mask). Change-out of carbon sorption systems will require the use of a forklift or other heavy equipment. Condensate water generated by the system will be collected into a 55 gallon drum. Proper drum handling procedures must be used to prevent physical injury (e.g., use a drum dolly).

If the equipment system is a fully enclosed building or trailer, while not technically a confined space, must be allowed to ventilate prior to entry. The contaminant concentration in the vapors from the SVE vent wells may be greater than exposure limits. If the piping or other air conveyance systems in the system develop any type of a leak, the air in the building/trailer will be allowed to ventilate prior to entry. Any potential confined space entry requires a confined space permit that will be developed on a site-specific basis prior to the entry.

Many remediation systems involve vacuum or pressurized lines. No vessel/container or lines to and from the vessels are to be opened while system is operating and under vacuum or pressure (even a very low pressure).

4.1.4 Electrical Safety

- Personnel will be trained in the operation of any electrical equipment to be used and maintain safe working practices when working around or handling electrical equipment or systems with supplied electricity.
- Notify appropriate supervisory personnel before and after conducting maintenance to any components of the system.
- Before attempting any operations and maintenance procedures on equipment locate the main electrical source and understand how to safely control it (turn on and off). Always verify (via direct measurement) that the electric source is disconnected before proceeding.
- To prevent accidental startup, or electrical connection, always lockout and tagout the electrical source before beginning any maintenance.
- Repairs or modifications to major components of the electrical system (electrical panels, electrical supply, etc.) must be made by a qualified electrician.

- During periods of lightning activity, do not connect or disconnect any cables or perform installation, maintenance, or reconfiguration of any system components.

WARNING LOCKOUT/TAGOUT PROCEDURES

High voltage and equipment with rotating parts can cause serious or fatal injury. Installation, operation, and maintenance of all equipment should be performed by qualified personnel. Appropriate lockout/tagout procedures must be followed for any maintenance work on all equipment with electrical connections and/or rotating parts, as per the requirements of OSHA CFR 29 Section 1910.147. This equipment is equipped with a remote telemetry/control system. The system may (potentially) be re-started remotely (over the remote control system via phone lines) by someone who is unaware of any maintenance work taking place. It is a critical safety concern that all equipment with electrical connections and/or rotating parts be positively disconnected and locked out before any maintenance work takes place.

4.2 Chemical Hazards

Hazardous chemicals that may be encountered at the Site include volatile organic compounds (VOCs). The primary COCs are PCE, TCE, cis-1,2-DCE, VC, and Cyanide. The most recent groundwater sampling was conducted in the Spring of 2014². In that event, the maximum concentration of PCE in groundwater was 1,100 micrograms per liter (µg/L). The maximum TCE concentration was 140 µg/L. The maximum 1,1-DCE concentration was 62 µg/L. The maximum cyanide concentration was 6.8 milligrams per liter (mg/L).

Safety and general health information (i.e., National Institute for Occupational Safety and Health [NIOSH] International Safety Card) are provided for anticipated chemicals present (See Attachment A). Field personnel should be able to recognize potential chemical hazard conditions and take appropriate precautions. Those precautions include respiratory protection, dermal protection, and control of equipment contamination. Field personnel should not work in potential chemical hazard areas unless they are fully trained in the evaluation of chemical hazards and appropriate protective measures, and are adequately equipped with personal protective equipment.

The four (4) exposure routes through which chemicals may potentially enter the body include inhalation, ingestion, absorption, and injection. These exposure pathways will be controlled to limit potential for exposure to chemical hazards and are addressed below:

- Inhalation of contaminants: Risk of inhalation of contaminants for this SOW is associated with routine monitoring of the SVE remediation system. On the pressure side of the SVE system vapors are routinely monitored using a photoionization detector, Tedlar bag, or SUMMA canister. When filling any sample container, personnel will take precautions to ensure all connections are air tight and do not breathe air from the immediate vicinity of the sampling port. No significant inhalation health hazards from chemical contaminants are anticipated for the groundwater monitoring or drilling phases of this SOW. Based on

² HydroGeologic, 2014 Final Groundwater Monitoring Report for the 20th Street and Factor Avenue WQARF Site, Yuma Arizona.

prior sampling results (several years of data), the concentrations of VOCs in groundwater are low enough that vapor inhalation associated with sampling and drilling work is considered to be a very low risk.

- Ingestion of contaminants: The likelihood of this occurring will be controlled by prohibiting eating, drinking, smoking, and chewing while working in the exclusion zone. Once outside the working area, workers shall remove gloves, and wash their hands and face before engaging in any of the above activities.
- Absorption of contaminants: Skin contact is the common cause of allergic contact dermatitis. Eyes are also very porous and contact with liquids can easily cause eye irritation/damage. This exposure pathway will be controlled by wearing eye protection, nitrile/latex gloves and protective clothing as necessary.
- Injection of contaminants: This typically occurs through misuse of sharp items. It will be controlled by wearing appropriate gloves in the work area and following safe work practices around tools, equipment and debris that have the potential for injection and/or punctures.

Note: the maximum concentrations of COCs detected at the Site over the last several years have documented that permissible exposure limits (PELs) in the breathing space is unlikely to be exceeded during remedial system operations or groundwater sampling activities; therefore, Level D personal protection equipment is adequate for groundwater sampling, and air monitoring is not required. Recommended maximum exposure limits for PCE are based on levels established by the American Conference of Governmental Industrial Hygienists (ACGIH) 25 ppm and a Time Weighted Average (TWA) of 100 ppm.

For cyanide, the ACGIH lists 5 milligrams per cubic meter (mg/m³) as a ceiling (as listed as Hydrogen cyanide and cyanide salts).

4.3 Biological Hazards

Typically, the live biological hazards that may be encountered during site activities are insects; most likely spiders (from inside the well monuments), and/or stinging/biting insects such as bees, wasps, ants, scorpions, etc. Field crews will be instructed to be cautious about where they place hands and feet when opening wellhead covers and to inspect the area thoroughly before proceeding with fieldwork.

First-aid training for all staff covers blood borne pathogens. All staff will implement universal precautions (treating all human blood or other potentially infectious materials [OPIM] as if known to be infectious for blood borne pathogens); first-aid kits will include appropriate gloves.

If an individual has a history of allergic reactions to insect bites, or is subject to attacks of hay fever or asthma, or if they are not promptly relieved of symptoms, call a physician or seek immediate emergency medical treatment. If a worker is highly sensitive (based on prior experience) and is subject to any type of reactions, do not wait for symptoms to appear, since delay can be fatal. Any individual with a known allergy to wasps and bees must notify the Project Manager prior to working at the project Site; those individuals will be required to carry the appropriate emergency first-aid equipment (prescription); oral antihistamines (e.g., Benadryl) and one or more EPI pens (epinephrine). Other site staff must be trained in use of this emergency first-aid equipment (covered in standard first-aid training).

Rattlesnakes and Africanized bees are common in Arizona but are less likely in a commercial/urban setting such as this Site.

4.4 Weather Related Hazards

If dangerous weather conditions such as electrical storms, high winds, or heavy rain create conditions which make field activities unsafe, then the Site Safety/Health Officer (SSHO) will terminate field work until conditions improve.

Heat stress may be the biggest health and safety concern when conducting Site activities, between late Spring and early Fall. Heat stress is a significant potential hazard that can be associated with very hot days, sun exposure, heavy physical activity and/or the use of personal protective equipment. Heat illness is more likely to occur among workers who have not been given time to adjust to working in a hot environment. It is important to stress the need for sunscreen, rest, drinking water, or electrolyte replacements to maintain proper electrolyte levels when working in hot climates (or when using personal protective equipment). To avoid working in the extreme temperatures (typically after 1 pm), work may begin in the early morning and may need illumination of the work area (if not illuminated by street lights).

4.4.1 Sunburn

Overexposure to ultraviolet (UV) radiation will cause sunburn and damage skin. Sunburn also increases an individual's susceptibility to other forms of heat illness/stress. Any worker with sunburn must pay extra attention to the prevention of heat cramps, heat exhaustion, and/or heat stroke.

The following methods can be used to avoid overexposure to sun:

- 1) Minimize exposure to direct sun between 10:00 a.m. and 3:00 p.m.
- 2) Wear protective clothing (long sleeves, hats with protective brim, long pants) that provides the most coverage, consistent with the job to be performed.
- 3) Protect eyes during sun exposure with UV-absorbing sunglasses or tinted safety glasses.
- 4) Use a commercial sun screen (minimum SPF-15) reapplied often.

4.4.2 Heat Illness/Stress

The potential for heat illness is present when the temperature exceeds 70° F. All staff must be alert for the signs of heat stress in themselves and other staff. "Self-observation" by field crew workers of their own physical condition along with a buddy system are important control mechanisms. Some signs and symptoms of heat illness/stress are presented below:

Heat Cramps/Heat Rash: Heat cramps usually affect workers who sweat a lot during strenuous activity. Dehydration and low salt levels in muscles causes painful cramps. *Heat cramps may also be a symptom of heat exhaustion.* Heat rash is a skin irritation caused by excessive sweating during hot, humid weather. Symptoms: Muscle pain or spasms usually in the abdomen, arms, or legs; heat rash typically looks like a red cluster of pimples or small blisters.

First aid includes: For rash, try to keep the affected area dry (use baby powder or other). Workers with heat cramps should; 1) Stop all activity, and sit in a cool place; 2) Drink clear juice or a sports beverage; 3) Do not return to strenuous work for a few hours after the cramps subside; further exertion may lead to heat exhaustion or heat stroke; 4) Seek medical attention if any of the following apply:

- 1) The worker has heart problems.
- 2) The worker is on a low-sodium diet.

3) The cramps do not subside within one hour.

Heat exhaustion occurs from increased stress on various body organs including inadequate blood circulation due to cardiovascular insufficiency or dehydration. Signs and symptoms include dizziness, headache, sweaty skin, fast heartbeat, nausea/ vomiting, and cramps. Heat exhaustion is dangerous but can typically be addressed on-site with shade, wet towels, and fanning to rapidly cool. The individual may be unable to work for the rest of the day. If the individual is not improving within 30 minutes and the body temperature has not decreased, the individual should be transported to a hospital for medical attention.

First-aid treatment (applies to heat exhaustion, not to heat stroke) includes:

- 1) Remove worker from hot area;
- 2) Have worker lie down and raise feet;
- 3) Apply cool wet cloths, fan to cool;
- 4) Loosen or remove clothing; and
- 5) Allow small sips of water or electrolyte replacement if the victim is not vomiting.

Heat stroke is the most serious form of heat illness; **HEAT STROKE IS A MEDICAL EMERGENCY.**

Signs and symptoms may include:

- hot, flushed (red), dry skin;
- nausea;
- headache; dizziness or vertigo;
- rapid heart rate;
- shortness of breath;
- confusion, delirium, or loss of consciousness; and
- convulsions.

This condition occurs when the core body temperature of an individual (exposed to excessive heat) exceeds 104 ° F. Heat stroke can occur suddenly without prior symptoms of heat exhaustion.

First-aid treatment: DIAL 911 & SEEK MEDICAL ATTENTION IMMEDIATELY; apply wet cloths, fan to cool while waiting for ambulance. Take immediate action to cool the body, serious injury and/or death can occur.

4.4.3 Heat Illness/Stress Monitoring

During field activities, personnel shall be monitored for heat stress. Monitoring for heat stress will consist of personnel constantly observing each other for any of the heat illness symptoms discussed above. A thermometer with disposable covers will be included in the Site first-aid kit. If any type of heat illness is observed (or suspected) oral temperature will be measured and personnel whose oral temperature exceeds 100.4° F will discontinue working until their temperature returns to a normal range of approximately 96.8° F to 100.4° F. If personnel are not sufficiently hydrated and/or appear to stop sweating (in hot weather), they will discontinue work until rehydrated.

Personnel will be required to drink bottled water or sports drink every 30 minutes (even if not thirsty) to minimize the risk of dehydration. Chilled bottled water, or sports drinks will be available at all times in an area away from potential contamination. Field personnel will wear a hat (wide brimmed) and light colored, loose fitting clothing. Long sleeve shirts and pants are recommended.

Field personnel will also apply sunscreen at the recommended application rates. The SSHO may mandate periods of rest in shade or work slowdowns as needed during extreme heat. A collapsible canopy will also be available for personnel for shade when performing work, or to provide an area to rest in the shade. The SSHO shall also monitor and support employee’s consumption of water and/or sports drink. Personnel will be reminded of the steps to take to prevent heat illness and review the emergency plan during tailgate meetings each day.

The heat index (HI) combines air temperature and relative humidity in an attempt to show the human-perceived equivalent temperature — how hot it feels. The following chart (Figure 3) shows heat index and possible heat stress disorders that may occur; the key planning detail is that conditions where heat stroke is possible will be encountered regularly.

Figure 3: NOAA Heat Index Chart (modified)

Heat Index Chart						
Temperature (F) versus Relative Humidity (%)						
Degrees F	90%	80%	70%	60%	50%	40%
80	85	84	82	81	80	79
85	101	96	92	90	86	84
90	121	113	105	99	94	90
95		133	122	113	105	98
100			142	129	118	109
105				148	133	121
110						135

Degrees F	Possible Heat Disorder
80-90	Fatigue possible with prolonged exposure and physical activity
90-105	Sunstroke, heat cramps and heat exhaustion possible
105-130	Sunstroke, heat cramps, heat exhaustion likely, heatstroke possible
130 or greater	Heatstroke highly likely with continued exposure

4.4.4 Cold Stress

Working outside in cold weather has associated safety concerns. Cold environments may challenge workers in three ways: by air temperature, air movement (wind), and wetness. These elements must be overcome by proper insulation (layered clothing), physical activity, and controlled exposure to cold conditions with an appropriate work schedule/intervals. As the body loses core temperature, the risk of hypothermia sets in. Some cold stress mitigation measures include:

- Engineering controls such as portable heaters, windbreaks, shelters, etc. may be used to lessen the effects of cold and wind.
- Get in a vehicle and turn on the heater (or other indoor heated space).
- Dress appropriately for the weather. Use layers of clothing rather than a single heavy garment. Be sure extremities (hands, feet, ears, etc.) are well covered. Keep clothing as dry as possible to increase insulating capability and decrease cooling effects.

4.5 Fire Hazards

All field personnel will abstain from the use of any open flame activities during field activities. If a generator is to be used, it will be placed in a location where there is no danger of fire. A fire extinguisher will be part of a safety kit (along with a first-aid kit and extra personal protective equipment [PPE]) in case a fire is encountered.

4.6 Site Communications

The primary form of site communication will be cell phones. Communications checks will be run at the start of each day; if teams are in separate areas, communications checks will occur approximately twice a day. Cell phones will be on or near field personnel at all times.

5.0 PERSONAL PROTECTIVE EQUIPMENT

PPE is defined as items that are worn and designed to protect the health and safety of an employee. This includes, but is not limited to, chemical-resistant shoes, boots, gloves, chemical protective clothing, hard hats, safety glasses, hearing protection, and respirators. Personnel will be reminded that when protective equipment is worn, visibility, hearing, and manual dexterity may be impaired.

Anyone entering the Site must be fully aware of and protected from potential hazards. The purpose of PPE is to shield or isolate individuals from the chemical and physical hazards that may be encountered on the Site and does not replace engineering controls.

5.1 Level D Protection

Based on maximum concentrations of Site contaminants, Level D personal protective equipment is expected to be the highest protective level required to safely complete the field activities for this project. The following list summarizes the Level D personal protective equipment that must be utilized while working on-site:

- Hardhat (if applicable, due to overhead equipment)
- Steel-toe boots (or other sturdy boots if no toe-crush hazards exist)
- Safety glasses (including splash shields, if splash hazard present)
- Work gloves and latex gloves (leather or equivalent for work and nitrile/latex used during groundwater sampling for sample collection)
- Long-leg trousers (light colored clothing preferred)
- Long sleeves (optional)
- Wide brimmed hat (when in the sun)
- Hearing protection (if applicable)

5.2 Dermal Protection

Dermal protection (i.e., protection of the skin) will be provided by using appropriate protective clothing. General site construction work will be performed wearing work boots and leather gloves. This level of PPE is appropriate where no splash hazards exist and potential exposures are limited to concentrations of chemicals below established exposure limits.

If working with highly-contaminated soils or water, personnel will wear impermeable coveralls, impermeable gloves (neoprene or nitrile/latex), and impermeable footwear. The garment joints at wrist and ankle will be sealed to the gloves and footwear with tape. For work with most soils and dilute aqueous solutions, the recommended garment is Saranex-coated Tyvek. This material is available in a wide variety of sizes and configurations. Recommended gloves are inner gloves of thin nitrile or latex rubber, with outer gloves of neoprene rubber. These materials are appropriate for most contaminated soils and dilute aqueous solutions. Required footwear is steel-toed boots made of either neoprene rubber or polyvinyl chloride (PVC). Both of these materials are highly resistant to most contaminants. The PM and SSO will assess the compatibility of these recommended materials with site contaminants and determine the need for modifications in PPE requirements.

If splash hazards exist, additional splash protection may be required. This may include full-face shields over goggles or respirators, and the use of special chemical splash suits.

5.3 Respiratory Protection

Project staff are expected to perform most system installation work in Level D respiratory protection (i.e., no respiratory protection equipment required with routine air monitoring). Occasionally, the use of Level C protection (i.e., air purifying respirators) may be required. Field personnel will keep APRs at the work site for use if Level C action levels are exceeded. Level A or B protection (i.e., self-contained or supplied air breathing apparatus) is not expected to be required on this site.

Appropriate respiratory protection will be used by employees whenever the concentration of airborne chemicals in the workers' breathing zone is expected to be above established exposure limits, current planned site activities are not expected to require respirators. Workers will keep to the upwind side of possible airborne contaminant sources whenever possible.

When or if APRs are required, employees will use respirators equipped with appropriate approved cartridges. Half mask APRs may be preferred for this Site due to heat concerns if respirators are required. All personnel using APRs must be FIT tested prior to using respiratory protection equipment and have clearance by a medical professional to wear a respirator.

5.4 Area Access Controls

Whenever specific dangerous activities are occurring as part of the planned work, access controls will be used to demarcate areas where only essential project personnel may enter. When drill rigs are operating, the controlled access area will be an area around the rig with a radius at least as high as the mast on the drill rig (where feasible). The controlled access area will be marked with cones and a high visibility tape. Site personnel will also be responsible to notify any other workers in the immediate vicinity of the controlled access area. Passage into and out of the controlled access area will be through a zone with appropriate decontamination facilities as necessary.

6.0 SITE CONTROL AND WORK ZONES

Perimeter exclusion zones will be setup using traffic cones, caution tape and/or candlestick delineators to establish a work safety zone to prevent pedestrians/vehicles from entering or disturbing the field work site. Prevention of unauthorized personnel is particularly important for this project due to its location in an industrial/business neighborhood. Authorized and unauthorized persons are expected to be encountered. When visitors come to any job site while Matrix-CALIBRE personnel are present, they will be approached and accompanied by the SSHO while at the job site.

6.1 Authorized Personnel

Only personnel who have completed forty (40) hours of hazardous waste operations training as defined under Occupational Safety and Health Administration (OSHA) Regulation 29 Code of Federal Regulations (CFR) 1910.120, and are current with the annual 8-hour refresher training, and have been medically certified as

fit³ for hazardous waste operations will be allowed within a Site work area. Additionally, only those personnel with the proper PPE will be allowed to enter the work zone. All records related to safety training and any other related records are maintained by the Matrix-CALIBRE Safety Program Manager in accordance with the Matrix-CALIBRE Health and Safety Program.

6.2 Tailgate Briefing

Daily safety meetings, detailing specific hazards of the work to be performed and safety precautions, will be conducted by the SSHO at the beginning of each workday and documented in writing (in a field log-book). No person will be allowed in the work exclusion zone without first being given a Site hazard briefing. In general, the briefing will consist of a review of the Tailgate Safety Meeting (see Attachment C). All people on the Site, including visitors, must sign the Health and Safety Compliance Agreement (Section 12).

6.3 Field Activity Log

Daily work activities shall be documented via a daily log completed by the SSHO. The SSHO shall record the names of all personnel working for Matrix-CALIBRE and any Site visitors. The SSHO shall also record any accidents, illness, and other safety related matters. In the case of an accident or injury during field operations, the SSHO will prepare and submit an Incident/Accident Report to the Project Manager and Matrix-CALIBRE Safety Manager.

6.4 Engineering Controls

The project manager and SSHO will evaluate the need for engineered controls to reduce exposures to airborne contaminants before initiating upgraded respiratory protection programs. Engineered controls can be as

³ Based on limited worker exposure to hazardous substances at or above the PELs or other published exposure limits (<30 days/year); limited use of respirators (<30 days/year); and no true HAZMAT response functions, the medical surveillance program required at this Site is also limited. The medical surveillance program provides that: 1) workers assigned to tasks requiring the use of respirators receive medical examinations in accordance with 29 CFR 1910.134(e) to ensure they are physically capable to perform the work and use the equipment; 2) if a worker is injured, becomes ill, or develops signs or symptoms of possible over-exposure to hazardous substances or health hazards, medical examinations are provided to that worker as soon as possible after the occurrence and as required by the attending physician. Medical exams and procedures are to be performed by or under the supervision of a licensed physician and are provided to employees free of cost, without loss of pay, and at a reasonable time and place. The need to implement a more comprehensive medical surveillance program will be re-evaluated in the event of any exposure incident.

simple as setting up a drill rig or conducting soil or groundwater sampling so that personnel are working on the upwind side. Alternative engineered controls include the use of enhanced ventilation at a work site (e.g., the use of electric fans) to reduce contaminant concentration by dilution, where appropriate. Enhanced ventilation is particularly useful around drill rigs and bore holes. Shielding may be used in some instances to protect workers from contaminants. Shielding can work by physically deflecting a flow of contaminants away from workers, or, as in the case of ionizing radiation, the shielding can physically reduce the amount of radiation reaching the workers. Exposures can also be reduced by drumming, or otherwise containerizing contaminated drill cuttings or other materials.

When drilling in areas of known or suspected high levels of subsurface contamination, the SSHO will ensure that the drillers have sufficient bentonite plug material available to securely plug the bore hole in the event of a discharge of high levels of volatiles or other air borne contaminants.

6.5 Contamination Avoidance

Most casual chemical exposures can be prevented by individual employees through contamination avoidance. The following practices will minimize the potential for casual exposure:

- No unauthorized personnel will be allowed to enter areas of known or suspected environmental contamination.
- All personnel will practice good personal hygiene during field operations. This includes washing face and hands after leaving any work area and before eating. Potentially contaminated work clothing will be decontaminated at the site and cleaned before re-use.
- No personnel will be allowed to eat, chew gum or tobacco, or smoke in any area of known or suspected contamination.
- All personnel and equipment will be decontaminated when leaving any area of known or suspected contamination in excess of exposure limits.

6.6 Site Monitoring

Air monitoring will be part of site safety for all field activities where there exists potential for exposure to airborne contaminants. The nature of the site contaminants (i.e., VOCs) indicates the need for an air monitoring program during specific phases of field work. Well drilling and construction, direct-push sampling, and remedial operations may be conducted in areas of elevated concentrations of volatile contaminants in groundwater and possibly soil.

The specific air monitoring requirements that are appropriate will depend on the conditions encountered and the type of work to be completed. A summary of the action levels associated with different monitoring parameters is presented in the chart Monitoring Equipment and Action Levels, below. The project manager and SSHO will confirm that the appropriate required air monitoring instruments are identified in the safety plan and are made available and used properly during site operations. All air monitoring instruments will be operated in accordance with manufacturer's operating instructions. All monitoring instruments used during installation and operation activities will be intrinsically safe.

For specific chemicals, three action levels will be defined, based on the need for enhanced respiratory protection. The initial action level will be 50 percent of the exposure limit measured in the breathing zone of the site workers. At the initial action level (also known as the Level C action level), the on-site personnel will take the appropriate response with enhanced personal protective equipment or modified work practices (e.g., engineered controls such as enhanced ventilation) to prevent worker exposures above the action level. The

response to the initial action level will generally be the use of air-purifying respirators (provided that the SSHO has determined that an appropriate, approved respirator is available). At this time, the SSHO will also assess the need for enhanced dermal protection.

The second action level for respiratory protection will be specified at 50 percent of the maximum use limit of the appropriate air-purifying respirator, measured in the site workers' breathing zone for a minimum period of 15 minutes. At this action level (also known as the Level B action level), the SSHO will assess the practicality of enhancing engineered controls (e.g., ventilation) to reduce concentrations. This plan will be modified if supplied air or self-contained breathing apparatus is required for site workers.

The third action level is the maximum use limit for air purifying respirators; this level requires specialty equipment such as Level B PPE with supplied air or self-contained breathing apparatus. If these conditions are encountered work will stop and the SSHO and Project Manager will discuss safe and practical methods to complete work. At any time during site operations when any action level is exceeded, the SSHO will immediately implement additional air monitoring at the work area, or exclusion zone boundary to ensure that the initial, or Level D, action level is not exceeded at the boundary. If the Level D action level is exceeded at the boundary of the exclusion zone, the SSHO will enlarge the exclusion zone adequately to prevent exposure of unprotected individuals.

Monitoring Equipment and Action Levels

Monitoring Equipment	Readings¹	Action
Explosimeter <i>(required if site is likely to have fuels or other flammable materials)</i>	< 5 % Lower explosive limit (LEL)	Continue with caution
	5-15 % LEL	Implement mechanical control measures such as forced ventilation, continue with caution
	> 15 % LEL	Stop work and evacuate area until readings are below 10 %LEL
Oxygen (O ₂) meter <i>(required if site is likely to have high concentrations that may depress O₂; fuels or other flammable materials)</i>	19.5–21% O ₂	Continue operations
	Needle deflects upward then drops to zero	Stop work and evacuate area until readings are approximately 20% O ₂
	< 19.5% O ₂	Stop work and evacuate area until readings are approximately 20% O ₂
	> 21% O ₂	Stop work and evacuate area until readings are approximately 20% O ₂
PID	< 1 ppmv	Continue operations in level D PPE
	>1 and < 10 ppmv intermittent	Upgrade to Level C PPE. Identify VOC type with colorimetric detector tube and attempt to locate source; monitor continuously. Resume work only if detector tube indicates VOC below PEL in breathing zone (refer to Section 9). Use engineered controls if necessary.
	> 10 ppmv	Stop operations, evacuate area.
Sound Level Meter	< 85 dB	Continue operations
	> 85 dB	Wear hearing protection to attenuate noise level below 85 dB
	> 120 dB	Continue operations if hearing protection attenuates noise levels below 85 dB; continue to monitor, implement acoustical control measures (noise buffers)

Note:

1 All readings are greater than background and taken in the breathing/hearing zone of field personnel.

Abbreviations:

dB Decibels

Ppmv Parts per million by volume

If odors or irritation of eyes or mucous membranes are noted by any personnel, work will be suspended and monitoring performed immediately to ensure the proper level of protection. Additional monitoring will be conducted during drilling when sample cores are taken from the boring.

7.0 DECONTAMINATION AND DISPOSAL PROCEDURES

7.1 Contamination Prevention

Good contamination prevention can minimize worker exposure and help ensure valid sample results by precluding cross-contamination. Procedures for contamination avoidance include the following:

- Do not walk through areas of obvious or known contamination;
- Do not handle or touch contaminated materials directly;
- Make sure all personal protective equipment has no cuts or tears prior to donning;
- Take particular care to protect any skin injuries;
- Stay upwind of potential airborne contaminants; and
- Do not carry cigarettes, gum, food, etc. into work/contaminated areas.

7.2 Decontamination

Field activities and sampling are expected to be conducted using Level D PPE. If contaminant contact has occurred, decontamination for activities requiring Level D protection will consist of the following:

- 1) Remove gloves and dispose (if for one-time use, or damaged);
- 2) Remove, wash, and rinse hard hat (if soiled);
- 3) Remove, wash, and rinse goggles/safety glasses;
- 4) Remove safety boots or shoes; and
- 5) Wash and rinse face and hands.

7.3 Site Cleanup and Disposal

Site cleanup will be performed at each well/sampling location after work has been completed and prior to moving to the next location. Field personnel will maintain clearly-identified containers for each of the three categories of waste if needed: [1] non-regulated solid waste; [2] undesignated solid waste that may be regulated; and [3] regulated waste. Routine sampling and operations are not expected to create regulated waste; if an activity is expected to create a regulated waste the appropriate labeled container will be prepared prior to initiating the activity.

The project manager will ensure that drums and other containers for regulated or potentially-regulated materials are clearly labeled with the contents. The project manager will also ensure that all containers of potentially-regulated materials are sampled and analyzed to determine the correct designation of the regulated or non-regulated waste.

Non-regulated dry solid wastes (e.g., disposable tools, gloves, plastic sheets, used rope, and rags) will be disposed properly by decontaminating the items, as needed, and packaging them in garbage bags and disposing of them by transporting to the nearest disposal facility.

Non-regulated aqueous wastes may be allowed to evaporate or will be disposed to the sanitary sewer, providing the liquids meet all pre-treatment standards or other requirements. The project manager will confirm the requirements for discharge of aqueous materials to the local sewer.

All purge water (including any unused water from the PDB samplers) and/or decontamination solutions will be containerized and sampled prior to disposal if contaminants are known or suspected to be present in the

solutions. The Sampling and Analysis Plan (SAP) will establish the analytical requirements and ultimate plans for management of investigation derived wastes (IDW). The PDB sampling technique does not generate purge water; therefore, the amount of IDW generated will be minimal.

8.0 SANITATION

- 1) Adequate washing facilities (portable bowl) will be provided including soap, water and towels.
- 2) Potable water and/or electrolyte-added sports drinks will be provided in sanitary containers at the job site in a chilled cooler.
- 3) Rest rooms are available in nearby commercial facilities (gas stations or fast-food restaurants), parks or libraries and may be available on the Houston site; a porta-potty should be rented for well drilling.

9.0 TRAINING REQUIREMENTS

All personnel assigned to this fieldwork will have completed, at a minimum, the appropriate formal training courses and maintained the appropriate refresher training. OSHA has determined that activities related to investigation and restoration at both known and potential hazardous waste sites (e.g., CERCLA or waste sites), fall under the scope of 29 CFR 1910.120. That standard requires 40 hours of initial training of the Hazardous Waste Operations and Emergency Response (HAZWOPER) and 8 hours annual refresher training, plus three days supervised on-site training for workers. An additional 8 hours of training are required for supervisors.

The SSHO will verify the credentials/training of all on-site personnel (based on records maintained by Matrix-CALIBRE Safety Program Manager). In order to be qualified for duty in exclusion zones or any other area where there is a potential for exposure to chemical contaminants, the following items must be current (i.e., conducted within the last 12 months preceding the expected date of completion of field operations): 8-Hour Annual Refresher Training (if 40-hour training was received more than 12 months prior). Additionally:

- At least one on-site Matrix-CALIBRE employee shall be current in cardiopulmonary resuscitation (CPR)/first-aid certification.
- Employees with the opportunity to use a portable fire extinguisher shall be familiarized as to use and fire safety principals.
- All employees will be familiar with the steps to take in case an employee displays signs of a heat-related illness (cold compress, rest in shade, proper hydration, and emergency route to hospital).

10.0 EMERGENCY RESPONSE PLAN

The following general emergency procedures are applicable to most planned Site activities. In the event of personnel exposure to hazardous chemical materials or personal injury at the Site, all work will stop immediately, and all personnel will assemble at the support area. First aid will be rendered as needed, or if necessary, an ambulance will be called. Response procedures for chemical exposure shall be prepared by consulting the product material safety data sheet (MSDS) and/or container labeling to implement/plan response.

Procedures for the specific chemicals anticipated at this site and potential exposures are as follows:

- Skin Contact: Flush the area with cold water for at least 15 minutes. Do not let contamination spread to other personnel. Seek medical attention. If injuries are severe, call an ambulance.
- Eye Contact: Wash/rinse affected area for at least 15 minutes, use a sink if accessible; other wise use bottled water. Seek medical attention.

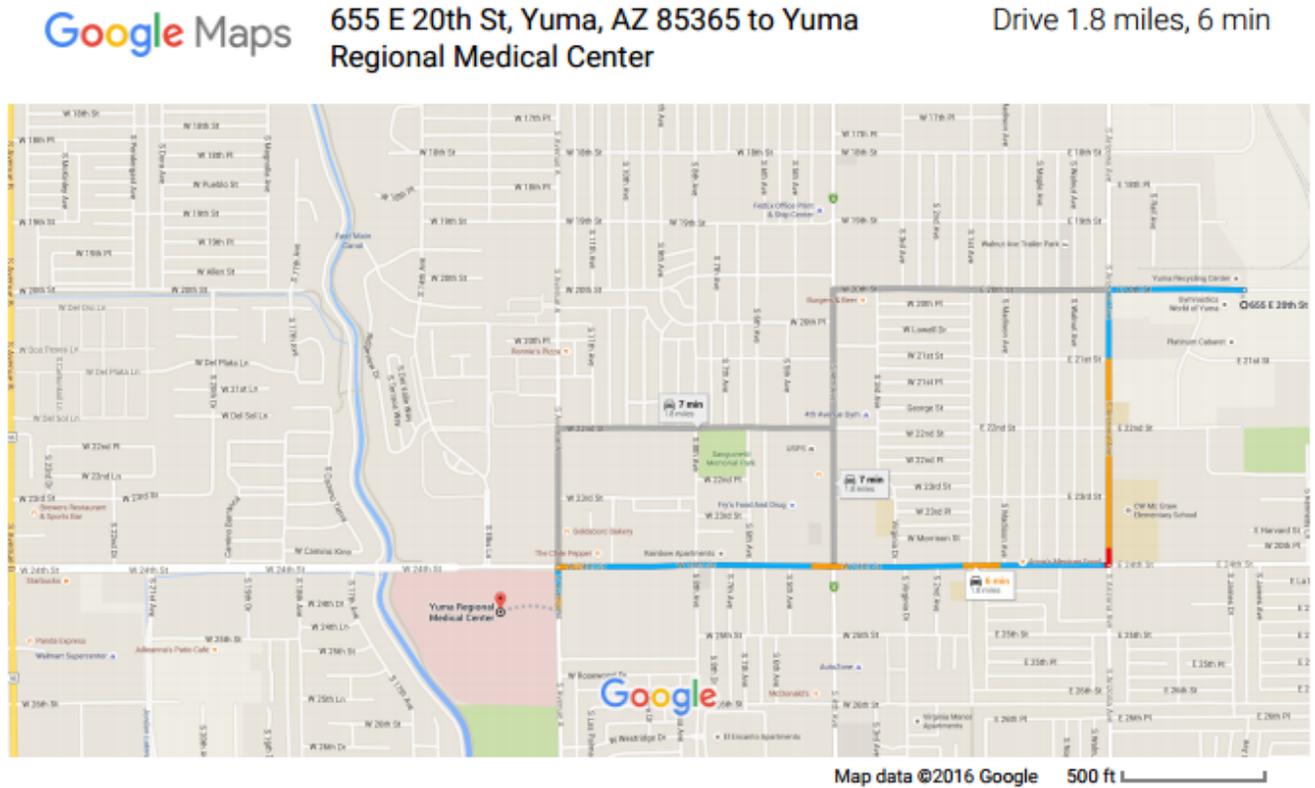
- Inhalation: Remove the person from further exposure. Call an ambulance, contact the hospital, and be prepared to provide respiratory support if the person has difficulty breathing.
- Ingestion: Dilute the material with large quantities of water. Call an ambulance and contact the hospital or poison control center immediately for further instructions.

In the event of a fire, explosion, or uncontrolled release of hazardous materials (e.g., a spill), all work will stop and all personnel will evacuate the Site to the upwind direction. The local fire department and/or HazMat team will be called and other personnel at the Site and neighboring locations will be notified of the hazard. If a fire is small and appears to be readily contained, personnel should use the on-site equipment (e.g., fire extinguishers, shovels, or water, as appropriate) to extinguish the fire. If the fire is extensive, or involves structures or vehicles, personnel will evacuate the Site, warn the occupants of neighboring facilities, and await the arrival of fire department personnel. Site workers will provide fire department personnel with as much information regarding the fire as possible. Critical information required by the fire department upon arrival will include the nature, location, and type of any hazardous or flammable materials present and any other hazards present.

In the event of an accident resulting in physical injury, first aid shall be administered and the injured worker shall be transported to the nearest medical facility Yuma Regional Medical Center (Figure 4). If an accident occurs, the SSHA is required to fill out an incident/accident report and submit it within 24 hours of the accident. Serious incidents (e.g., amputation, burn, disfigurement, hospitalization for more than 24 hours for other than observation, fatality) must be reported to management immediately and to OSHA within 8 hours.

Figure 4: Hospital route. From Facility to Yuma Regional Medical Center (Google, 2015)

20400 South Avenue A, Yuma, AZ 85364



655 E 20th St
Yuma, AZ 85365

- ↑ 1. Head west on E 20th St toward S Factor Ave
0.2 mi
- ↶ 2. Turn left at the 2nd cross street onto S Arizona Ave
0.5 mi
- ↷ 3. Turn right onto E 24th St
1.0 mi
- ↶ 4. Turn left onto S Avenue A
Destination will be on the right
433 ft

Yuma Regional Medical Center
2400 South Avenue A, Yuma, AZ 85364

11.0 KEY SAFETY PERSONNEL AND RESPONSIBILITIES

All personnel working for the Matrix-CALIBRE team are responsible for project safety. Emergency contacts are listed on page ii. Specific individual responsibilities are listed below:

Project Manager: Tom McKeon (425) 241-8449

The project manager is responsible for preparation/approval of this of this HASP. He has the authority to initiate an audit of compliance with the provisions in this HASP, to suspend or modify work practices, and to remove any individuals whose conduct does not meet the provisions presented in this HASP.

Site Safety/Health Officer (SSHO): Justin Neste (360) 981-5606

The Site Safety/Health Officer (SSHO) is responsible for the dissemination of the information contained in this HASP to all Matrix-CALIBRE personnel (and their subcontractors) working at this Site. The SSHO is responsible for ensuring that the following items are adequately addressed:

- Inspection of tools, and safety equipment
- Safety supplies and equipment inventory
- Site-specific training/hazard communication
- Accident/incident reporting
- Decontamination/contamination reduction procedures

The SSHO shall be responsible for taking necessary steps to ensure that employees are alert to and protected from chemical and physical hazards. Additionally, the SSHO has the authority to suspend work anytime he determines the safety provisions set forth in the HASP are inadequate to ensure worker safety. The SSHO (or his designee) must be present during all phases of the site work. The SSHO listed above may change and his/her designee will be documented in field logbooks and other related field notes (this HASP will not be re-issued with a new designee as SSHO, rather the name will be added [handwritten above] to the field paper copy of this HASP and on page ii).

12.0 HEALTH AND SAFETY COMPLIANCE AGREEMENT

Plan verification is an essential part of the plan and forms the basis for obligating personnel to comply with requirements presented in this plan.

I have read and understand the Health and Safety Plan and I will comply with the minimum safety requirements set forth in this Plan. I agree to notify the responsible Matrix-CALIBRE employee should any unsafe acts and / or unsafe conditions be witnessed by me while I am on this Site.

Print Name	Company	Signature	Date
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
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_____	_____	_____	_____

ATTACHMENT A:

MSDS/NIOSH CARDS:

PCE,

TCE,

1,2-DCE (including cis and trans isomers),

VC,

and Cyanide

International Chemical Safety Cards

TETRACHLOROETHYLENE

ICSC: 0076

1,1,2,2-Tetrachloroethylene
 Perchloroethylene
 Tetrachloroethene
 $C_2Cl_4 / Cl_2C=CCl_2$
 Molecular mass: 165.8

ICSC # 0076
 CAS # 127-18-4
 RTECS # KX3850000
 UN # 1897
 EC # 602-028-00-4
 April 13, 2000 Validated

TYPES OF HAZARD/ EXPOSURE	ACUTE HAZARDS/ SYMPTOMS	PREVENTION	FIRST AID/ FIRE FIGHTING
FIRE	Not combustible. Gives off irritating or toxic fumes (or gases) in a fire.		In case of fire in the surroundings: use appropriate extinguishing media.
EXPLOSION			
EXPOSURE		STRICT HYGIENE! PREVENT GENERATION OF MISTS!	
•INHALATION	Dizziness. Drowsiness. Headache. Nausea. Weakness. Unconsciousness.	Ventilation, local exhaust, or breathing protection.	Fresh air, rest. Artificial respiration may be needed. Refer for medical attention.
•SKIN	Dry skin. Redness.	Protective gloves. Protective clothing.	Remove contaminated clothes. Rinse and then wash skin with water and soap.
•EYES	Redness. Pain.	Safety goggles , face shield .	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then take to a doctor.
•INGESTION	Abdominal pain. (Further see Inhalation).	Do not eat, drink, or smoke during work.	Rinse mouth. Do NOT induce vomiting. Give plenty of water to drink. Rest.
SPILLAGE DISPOSAL	STORAGE		PACKAGING & LABELLING
Ventilation. Collect leaking and spilled liquid in sealable containers as far as possible. Absorb remaining liquid in sand or inert absorbent and	Separated from metals ,(see Chemical Dangers), food and feedstuffs . Keep in the dark. Ventilation along the floor.		Do not transport with food and feedstuffs. Marine pollutant. Xn symbol

remove to safe place. Do NOT let this chemical enter the environment. Personal protection: filter respirator for organic gases and vapours.	N symbol R: 40-51/53 S: (2-)23-36/37-61 UN Hazard Class: 6.1 UN Packing Group: III
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SEE IMPORTANT INFORMATION ON BACK

ICSC: 0076

Prepared in the context of cooperation between the International Programme on Chemical Safety & the Commission of the European Communities (C) IPCS CEC 1994. No modifications to the International version have been made except to add the OSHA PELs, NIOSH RELs and NIOSH IDLH values.

International Chemical Safety Cards

TETRACHLOROETHYLENE

ICSC: 0076

I M P O R T A N T I N F O R M A T I O N	<p>PHYSICAL STATE; APPEARANCE: COLOURLESS LIQUID , WITH CHARACTERISTIC ODOUR.</p> <p>PHYSICAL DANGERS: The vapour is heavier than air.</p> <p>CHEMICAL DANGERS: On contact with hot surfaces or flames this substance decomposes forming toxic and corrosive fumes (hydrogen chloride, phosgene, chlorine). The substance decomposes slowly on contact with moisture producing trichloroacetic acid and hydrochloric acid. Reacts with metals such as aluminium, lithium, barium, beryllium.</p> <p>OCCUPATIONAL EXPOSURE LIMITS: TLV: 25 ppm as TWA, 100 ppm as STEL; A3 (confirmed animal carcinogen with unknown relevance to humans); BEI issued; (ACGIH 2004). MAK: skin absorption (H); Carcinogen category: 3B; (DFG 2004). OSHA PEL[†]: TWA 100 ppm C 200 ppm 300 ppm (5-minute maximum peak in any 3-hours) NIOSH REL: Ca Minimize workplace exposure concentrations. See Appendix A NIOSH IDLH: Ca 150 ppm See: 127184</p>	<p>ROUTES OF EXPOSURE: The substance can be absorbed into the body by inhalation and by ingestion.</p> <p>INHALATION RISK: A harmful contamination of the air will be reached rather slowly on evaporation of this substance at 20°C.</p> <p>EFFECTS OF SHORT-TERM EXPOSURE: The substance is irritating to the eyes , the skin and the respiratory tract . If this liquid is swallowed, aspiration into the lungs may result in chemical pneumonitis. The substance may cause effects on the central nervous system. Exposure at high levels may result in unconsciousness.</p> <p>EFFECTS OF LONG-TERM OR REPEATED EXPOSURE: Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the liver and kidneys. This substance is probably carcinogenic to humans.</p>
	<p>PHYSICAL PROPERTIES</p>	<p>Boiling point: 121°C Melting point: -22°C Relative density (water = 1): 1.6 Solubility in water, g/100 ml at 20°C: 0.015</p>

ENVIRONMENTAL DATA	The substance is toxic to aquatic organisms. The substance may cause long-term effects in the aquatic environment.	
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NOTES

Depending on the degree of exposure, periodic medical examination is suggested. The odour warning when the exposure limit value is exceeded is insufficient. Do NOT use in the vicinity of a fire or a hot surface, or during welding. An added stabilizer or inhibitor can influence the toxicological properties of this substance, consult an expert. Card has been partly updated in April 2005. See section Occupational Exposure Limits.

Transport Emergency Card: TEC (R)-61S1897

NFPA Code: H2; F0; R0;

ADDITIONAL INFORMATION

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ICSC: 0076	(C) IPCS, CEC, 1994	TETRACHLOROETHYLENE
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International Chemical Safety Cards

TRICHLOROETHYLENE

ICSC: 0081

1,1,2-Trichloroethylene
 Trichloroethene
 Ethylene trichloride
 Acetylene trichloride
 C_2HCl_3 / $ClCH=CCl_2$
 Molecular mass: 131.4

ICSC # 0081
 CAS # 79-01-6
 RTECS # [KX4550000](#)
 UN # 1710
 EC # 602-027-00-9
 April 10, 2000 Validated

TYPES OF HAZARD/ EXPOSURE	ACUTE HAZARDS/ SYMPTOMS	PREVENTION	FIRST AID/ FIRE FIGHTING
FIRE	Combustible under specific conditions. See Notes.		In case of fire in the surroundings: all extinguishing agents allowed.
EXPLOSION		Prevent build-up of electrostatic charges (e.g., by grounding).	In case of fire: keep drums, etc., cool by spraying with water.
EXPOSURE		PREVENT GENERATION OF MISTS! STRICT HYGIENE!	
•INHALATION	Dizziness. Drowsiness. Headache. Weakness. Nausea. Unconsciousness.	Ventilation, local exhaust, or breathing protection.	Fresh air, rest. Artificial respiration may be needed. Refer for medical attention.
•SKIN	Dry skin. Redness.	Protective gloves.	Remove contaminated clothes. Rinse and then wash skin with water and soap.
•EYES	Redness. Pain.	Safety spectacles, or eye protection in combination with breathing protection.	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then take to a doctor.
•INGESTION	Abdominal pain. (Further see Inhalation).	Do not eat, drink, or smoke during work.	Rinse mouth. Do NOT induce vomiting. Give one or two glasses of water to drink. Rest.
SPILLAGE DISPOSAL	STORAGE	PACKAGING & LABELLING	
Ventilation. Personal protection: filter respirator for organic gases and vapours adapted to the airborne	Separated from metals (see Chemical Dangers), strong bases, food and feedstuffs . Dry. Keep in the dark.	Do not transport with food and feedstuffs. Marine pollutant.	

concentration of the substance. Collect leaking and spilled liquid in sealable containers as far as possible. Absorb remaining liquid in sand or inert absorbent and remove to safe place. Do NOT let this chemical enter the environment.	Ventilation along the floor. Store in an area without drain or sewer access.	T symbol R: 45-36/38-52/53-67 S: 53-45-61 UN Hazard Class: 6.1 UN Packing Group: III
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SEE IMPORTANT INFORMATION ON BACK

ICSC: 0081

Prepared in the context of cooperation between the International Programme on Chemical Safety & the Commission of the European Communities (C) IPCS CEC 1994. No modifications to the International version have been made except to add the OSHA PELs, NIOSH RELs and NIOSH IDLH values.

International Chemical Safety Cards

TRICHLOROETHYLENE

ICSC: 0081

<p>I</p> <p>M</p> <p>P</p> <p>O</p> <p>R</p> <p>T</p> <p>A</p> <p>N</p> <p>T</p> <p>D</p> <p>A</p> <p>T</p> <p>A</p>	<p>PHYSICAL STATE; APPEARANCE: COLOURLESS LIQUID , WITH CHARACTERISTIC ODOUR.</p> <p>PHYSICAL DANGERS: The vapour is heavier than air. As a result of flow, agitation, etc., electrostatic charges can be generated.</p> <p>CHEMICAL DANGERS: On contact with hot surfaces or flames this substance decomposes forming toxic and corrosive fumes (phosgene , hydrogen chloride). The substance decomposes on contact with strong alkali producing dichloroacetylene , which increases fire hazard. Reacts violently with metal powders such as magnesium, aluminium, titanium, and barium. Slowly decomposed by light in presence of moisture, with formation of corrosive hydrochloric acid.</p> <p>OCCUPATIONAL EXPOSURE LIMITS: TLV: 50 ppm as TWA; 100 ppm as STEL; A5; BEI issued; (ACGIH 2004). MAK: Carcinogen category: 1; Germ cell mutagen group: 3B; (DFG 2007). OSHA PEL[±]: TWA 100 ppm C 200 ppm 300 ppm (5-minute maximum peak in any 2 hours) NIOSH REL: Ca See Appendix A See Appendix C NIOSH IDLH: Ca 1000 ppm See: 79016</p>	<p>ROUTES OF EXPOSURE: The substance can be absorbed into the body by inhalation and by ingestion.</p> <p>INHALATION RISK: A harmful contamination of the air can be reached rather quickly on evaporation of this substance at 20°C.</p> <p>EFFECTS OF SHORT-TERM EXPOSURE: The substance is irritating to the eyes and the skin . Swallowing the liquid may cause aspiration into the lungs with the risk of chemical pneumonitis. The substance may cause effects on the central nervous system , resulting in respiratory failure . Exposure could cause lowering of consciousness.</p> <p>EFFECTS OF LONG-TERM OR REPEATED EXPOSURE: Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the central nervous system , resulting in loss of memory. The substance may have effects on the liver and kidneys (see Notes). This substance is probably carcinogenic to humans.</p>
	<p>PHYSICAL PROPERTIES</p> <p>Boiling point: 87°C Melting point: -73°C</p>	<p>Relative density of the vapour/air-mixture at 20°C (air = 1): 1.3</p>

	Relative density (water = 1): 1.5 Solubility in water, g/100 ml at 20°C: 0.1 Vapour pressure, kPa at 20°C: 7.8 Relative vapour density (air = 1): 4.5	Auto-ignition temperature: 410°C Explosive limits, vol% in air: 8-10.5 Octanol/water partition coefficient as log Pow: 2.42 Electrical conductivity: 800pS/m
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ENVIRONMENTAL DATA

The substance is harmful to aquatic organisms. The substance may cause long-term effects in the aquatic environment.



NOTES

Combustible vapour/air mixtures difficult to ignite, may be developed under certain conditions. Use of alcoholic beverages enhances the harmful effect. Depending on the degree of exposure, periodic medical examination is suggested. The odour warning when the exposure limit value is exceeded is insufficient. Do NOT use in the vicinity of a fire or a hot surface, or during welding. An added stabilizer or inhibitor can influence the toxicological properties of this substance, consult an expert.

Transport Emergency Card: TEC (R)-61S1710

NFPA Code: H2; F1; R0;

Card has been partially updated in October 2004: see Occupational Exposure Limits, EU Classification, Emergency Response.

Card has been partially updated in April 2010: see Occupational Exposure Limits, Ingestion First Aid, Storage.

ADDITIONAL INFORMATION

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ICSC: 0081

TRICHLOROETHYLENE

(C) IPCS, CEC, 1994

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International Chemical Safety Cards

1,2-DICHLOROETHYLENE

ICSC: 0436

	
<p>1,2-Dichloroethene Acetylene dichloride symmetrical Dichloroethylene $C_2H_2Cl_2$ / ClCH=CHCl Molecular mass: 96.95 ICSC # 0436 CAS # 540-59-0 RTECS # KV9360000 UN # 1150 EC # 602-026-00-3 July 05, 2003 Validated</p>	
	

TYPES OF HAZARD/ EXPOSURE	ACUTE HAZARDS/ SYMPTOMS	PREVENTION	FIRST AID/ FIRE FIGHTING
FIRE	Highly flammable. Gives off irritating or toxic fumes (or gases) in a fire.	NO open flames, NO sparks, and NO smoking.	Powder, water spray, foam, carbon dioxide.
EXPLOSION	Vapour/air mixtures are explosive.	Closed system, ventilation, explosion-proof electrical equipment and lighting. Do NOT use compressed air for filling, discharging, or handling.	In case of fire: keep drums, etc., cool by spraying with water.
EXPOSURE		STRICT HYGIENE!	
•INHALATION	Cough. Sore throat. Dizziness. Nausea. Drowsiness. Weakness. Unconsciousness. Vomiting.	Ventilation, local exhaust, or breathing protection.	Fresh air, rest. Refer for medical attention.
•SKIN	Dry skin.	Protective gloves.	Remove contaminated clothes. Rinse skin with plenty of water or shower.
•EYES	Redness. Pain.	Safety spectacles.	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then take to a doctor.
•INGESTION	Abdominal pain. (Further see Inhalation).	Do not eat, drink, or smoke during work.	Rinse mouth. Give plenty of water to drink. Refer for medical attention.
SPILLAGE DISPOSAL	STORAGE		PACKAGING & LABELLING
Remove all ignition sources. Ventilation. Collect leaking and	Fireproof. Well closed. See Chemical Dangers.		Note: C

spilled liquid in sealable containers as far as possible. Absorb remaining liquid in dry sand or inert absorbent and remove to safe place. Do NOT wash away into sewer. (Extra personal protection: complete protective clothing including self-contained breathing apparatus.)		F symbol Xn symbol R: 11-20-52/53 S: 2-7-16-29-61 UN Hazard Class: 3 UN Packing Group: II
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SEE IMPORTANT INFORMATION ON BACK

ICSC: 0436

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International Chemical Safety Cards

1,2-DICHLOROETHYLENE

ICSC: 0436

I M P O R T A N T D A T A	<p>PHYSICAL STATE; APPEARANCE: COLOURLESS LIQUID , WITH CHARACTERISTIC ODOUR.</p> <p>PHYSICAL DANGERS: The vapour is heavier than air and may travel along the ground; distant ignition possible.</p> <p>CHEMICAL DANGERS: The substance decomposes on heating or under the influence of air , light and moisture producing toxic and corrosive fumes including hydrogen chloride . Reacts with strong oxidants. Reacts with copper or copper alloys, and bases to produce toxic chloroacetylene which is spontaneously flammable in contact with air. Attacks plastic.</p> <p>OCCUPATIONAL EXPOSURE LIMITS: TLV: 200 ppm as TWA; (ACGIH 2003). MAK: 200 ppm, 800 mg/m³; Peak limitation category: II(2); (DFG 2002). OSHA PEL: TWA 200 ppm (790 mg/m³) NIOSH REL: TWA 200 ppm (790 mg/m³) NIOSH IDLH: 1000 ppm See: 540590</p>	<p>ROUTES OF EXPOSURE: The substance can be absorbed into the body by inhalation of its vapour and by ingestion.</p> <p>INHALATION RISK: A harmful contamination of the air will be reached quickly on evaporation of this substance at 20°C; on spraying or dispersing, however, much faster.</p> <p>EFFECTS OF SHORT-TERM EXPOSURE: The substance is irritating to the eyes and the respiratory tract . The substance may cause effects on the central nervous system at high levels , resulting in lowering of consciousness .</p> <p>EFFECTS OF LONG-TERM OR REPEATED EXPOSURE: The liquid defats the skin. The substance may have effects on the liver .</p>
PHYSICAL PROPERTIES	Boiling point: 55°C Relative density (water = 1): 1.28 Solubility in water: poor Relative vapour density (air = 1): 3.34	Flash point: 2°C c.c. Auto-ignition temperature: 460°C Explosive limits, vol% in air: 9.7-12.8 Octanol/water partition coefficient as log Pow: 2
ENVIRONMENTAL DATA		

NOTES

This compound has two isomers, cis and trans. Data for the isomers: cis-isomer (CAS 156-59-2), trans isomer (CAS 156-60-5), other boiling point 60.3, melting point -81.5°C (cis), -49.4°C (trans); flash point c.c. 6°C (cis), 2-4°C (trans); relative density (water = 1) 1.28 (cis), 1.26 (trans); vapour pressure 24.0 kPa (cis), 35.3 kPa (trans) at 20°C; relative density of the vapour/air-mixture at 20°C (air = 1): 1.6 (cis), 1.8 (trans); octanol/water partition coefficient as log Pow: 1.86 (cis), 2.09 (trans). Depending on the degree of exposure, periodic medical examination is suggested.

Transport Emergency Card: TEC (R)-30GF1-I+II

NFPA Code: H2; F3; R2;

ADDITIONAL INFORMATION

ICSC: 0436

1,2-DICHLOROETHYLENE

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International Chemical Safety Cards

VINYL CHLORIDE

ICSC: 0082






Chloroethene
Chloroethylene
VCM
C₂H₃Cl / H₂C=CHCl
Molecular mass: 62.5
(cylinder)
ICSC # 0082
CAS # 75-01-4
RTECS # [KU9625000](#)
UN # 1086 (stabilized)
EC # 602-023-00-7
April 13, 2000 Validated




TYPES OF HAZARD/ EXPOSURE	ACUTE HAZARDS/ SYMPTOMS	PREVENTION	FIRST AID/ FIRE FIGHTING
FIRE	Extremely flammable. Gives off irritating or toxic fumes (or gases) in a fire.	NO open flames, NO sparks, and NO smoking.	Shut off supply; if not possible and no risk to surroundings, let the fire burn itself out; in other cases extinguish with powder, carbon dioxide.
EXPLOSION	Gas/air mixtures are explosive.	Closed system, ventilation, explosion-proof electrical equipment and lighting. Use non-sparking handtools.	In case of fire: keep cylinder cool by spraying with water. Combat fire from a sheltered position.
EXPOSURE		AVOID ALL CONTACT!	IN ALL CASES CONSULT A DOCTOR!
•INHALATION	Dizziness. Drowsiness. Headache. Unconsciousness.	Ventilation, local exhaust, or breathing protection.	Fresh air, rest. Refer for medical attention.
•SKIN	ON CONTACT WITH LIQUID: FROSTBITE.	Protective gloves. Cold-insulating gloves. Protective clothing.	ON FROSTBITE: rinse with plenty of water, do NOT remove clothes.
•EYES	Redness. Pain.	Safety goggles or eye protection in combination with breathing protection.	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then take to a doctor.
•INGESTION		Do not eat, drink, or smoke during work.	
SPILLAGE DISPOSAL	STORAGE	PACKAGING & LABELLING	

Evacuate danger area! Consult an expert! Ventilation. Remove all ignition sources. Personal protection: complete protective clothing including self-contained breathing apparatus.	Fireproof. Separated from incompatible materials .(See Chemical Dangers.) Cool. Store only if stabilized.	Note: D F+ symbol T symbol R: 45-12 S: 53-45 UN Hazard Class: 2.1
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SEE IMPORTANT INFORMATION ON BACK

ICSC: 0082

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International Chemical Safety Cards

VINYL CHLORIDE

ICSC: 0082

<p>I M P O R T A N T D A T A</p>	<p>PHYSICAL STATE; APPEARANCE: COLOURLESS COMPRESSED LIQUEFIED GAS , WITH CHARACTERISTIC ODOUR.</p> <p>PHYSICAL DANGERS: The gas is heavier than air, and may travel along the ground; distant ignition possible. Vinyl chloride monomer vapours are uninhibited and may form polymers in vents or flame arresters of storage tanks, resulting in blockage of vents.</p> <p>CHEMICAL DANGERS: The substance can under specific circumstances form peroxides, initiating explosive polymerization. The substance will polymerize readily due to heating and under the influence of air, light and on contact with a catalyst, strong oxidizing agents and metals such as copper and aluminium, with fire or explosion hazard. The substance decomposes on burning producing toxic and corrosive fumes (hydrogen chloride , phosgene). Attacks iron and steel in the presence of moisture.</p> <p>OCCUPATIONAL EXPOSURE LIMITS: TLV: 1 ppm as TWA; A1 (confirmed human carcinogen); (ACGIH 2004). MAK: Carcinogen category: 1; (DFG 2004). OSHA PEL: 1910.1017 TWA 1 ppm C 5 ppm 15-minute NIOSH REL: Ca See Appendix A NIOSH IDLH: Ca N.D. See: IDLH INDEX</p>	<p>ROUTES OF EXPOSURE: The substance can be absorbed into the body by inhalation.</p> <p>INHALATION RISK: A harmful concentration of this gas in the air will be reached very quickly on loss of containment.</p> <p>EFFECTS OF SHORT-TERM EXPOSURE: The substance is irritating to the eyes . The liquid may cause frostbite. The substance may cause effects on the central nervous system . Exposure could cause lowering of consciousness. Medical observation is indicated.</p> <p>EFFECTS OF LONG-TERM OR REPEATED EXPOSURE: The substance may have effects on the liver, spleen, blood and peripheral blood vessels, and tissue and bones of the fingers. This substance is carcinogenic to humans.</p>
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<p>PHYSICAL PROPERTIES</p>	<p>Boiling point: -13°C Melting point: -154°C Relative density (water = 1): 0.9 (liquid) Density: 8 (vapour) at 15°C g/l Solubility in water: none</p> <p>Relative vapour density (air = 1): 2.2 Flash point: -78°C c.c. Auto-ignition temperature: 472°C Explosive limits, vol% in air: 3.6-33 Octanol/water partition coefficient as log Pow: 0.6</p>
<p>ENVIRONMENTAL DATA</p>	<p>This substance may be hazardous to the environment; special attention should be given to ground water contamination.</p> 
<p style="text-align: center;">NOTES</p>	
<p>Depending on the degree of exposure, periodic medical examination is suggested. The odour warning when the exposure limit value is exceeded is insufficient. Do NOT use in the vicinity of a fire or a hot surface, or during welding. An added stabilizer or inhibitor can influence the toxicological properties of this substance, consult an expert. Card has been partly updated in April 2005. See section Occupational Exposure Limits.</p> <p style="text-align: right;">Transport Emergency Card: TEC (R)-20S1086 NFPA Code: H 2; F 4; R 2;</p>	
<p style="text-align: center;">ADDITIONAL INFORMATION</p>	
<p> </p>	
<p>ICSC: 0082</p>	<p style="text-align: right;">VINYL CHLORIDE</p> <p style="text-align: center;">(C) IPCS, CEC, 1994</p>
<p>IMPORTANT LEGAL NOTICE:</p>	<p>Neither NIOSH, the CEC or the IPCS nor any person acting on behalf of NIOSH, the CEC or the IPCS is responsible for the use which might be made of this information. This card contains the collective views of the IPCS Peer Review Committee and may not reflect in all cases all the detailed requirements included in national legislation on the subject. The user should verify compliance of the cards with the relevant legislation in the country of use. The only modifications made to produce the U.S. version is inclusion of the OSHA PELs, NIOSH RELs and NIOSH IDLH values.</p>



Search the NIOSH Pocket Guide

Enter search terms separated by spaces.

Sodium cyanide (as CN)

Synonyms & Trade Names Sodium salt of hydrocyanic acid

CAS No. 143-33-9	RTECS No. VZ7525000 (/niosh-rtecs/VZ72D288.html)	DOT ID & Guide 1689 157 (http://wwwapps.tc.gc.ca/saf-sec-sur/3/erg-gmu/erg/guidepage.aspx/guide157/) (http://www.cdc.gov/Other/disclaimer.html) (solid) 3414 157 (http://wwwapps.tc.gc.ca/saf-sec-sur/3/erg-gmu/erg/guidepage.aspx/guide157/) (http://www.cdc.gov/Other/disclaimer.html) (solution)
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Formula NaCN	Conversion	IDLH 25 mg/m ³ (as CN) See: cyanides (/niosh/idlh/cyanides.html)
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Exposure Limits NIOSH REL *: C 5 mg/m ³ (4.7 ppm) [10-minute] [*Note: The REL also applies to other cyanides (as CN) except Hydrogen cyanide.] OSHA PEL *: TWA 5 mg/m ³ [*Note: The PEL also applies to other cyanides (as CN) except Hydrogen cyanide.]	Measurement Methods NIOSH 6010 (/niosh/docs/2003-154/pdfs/6010.pdf), 7904 (/niosh/docs/2003-154/pdfs/7904.pdf) See: NMAM (/niosh/docs/2003-154/) or OSHA Methods (http://www.osha.gov/dts/sltc/methods/index.html) (http://www.cdc.gov/Other/disclaimer.html)
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Physical Description White, granular or crystalline solid with a faint, almond-like odor.

MW: 49.0	BP: 2725° F	MLT: 1047°F	Sol (77° F): 58%	VP: 0 mmHg (approx)	IP: NA
Sp.Gr: 1.60	FLP: NA	UEL: NA	LEL: NA		

Noncombustible Solid, but contact with acids releases highly flammable hydrogen cyanide.

Incompatibilities & Reactivities Strong oxidizers (such as acids, acid salts, chlorates & nitrates)
[Note: Absorbs moisture from the air forming a syrup.]

Exposure Routes inhalation, skin absorption, ingestion, skin and/or eye contact

Symptoms irritation eyes, skin; asphyxia; lassitude (weakness, exhaustion), headache, confusion; nausea, vomiting; increased resp rate; slow gasping respiration; thyroid, blood changes

Target Organs Eyes, skin, cardiovascular system, central nervous system, thyroid, blood

Personal Protection/Sanitation (See [protection codes \(protect.html\)](#))
Skin: Prevent skin contact
Eyes: Prevent eye contact
Wash skin: When contaminated
Remove: When wet or contaminated
Change: Daily
Provide: Eyewash, Quick drench

First Aid (See [procedures \(firstaid.html\)](#))
Eye: Irrigate immediately
Skin: Soap wash immediately
Breathing: Respiratory support
Swallow: Medical attention immediately

Respirator Recommendations
NIOSH/OSHA

Up to 25 mg/m³:
 (APF = 10) Any supplied-air respirator
 (APF = 50) Any self-contained breathing apparatus with a full facepiece

Emergency or planned entry into unknown concentrations or IDLH conditions:
 (APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode
 (APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:
 (APF = 50) Any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted canister providing protection against the compound of concern and having an N100, R100, or P100 filter.

[Click here \(pgintrod.html#nrp\)](#) for information on selection of N, R, or P filters.
 Any appropriate escape-type, self-contained breathing apparatus

[Important additional information about respirator selection \(pgintrod.html#mustread\)](#)

See also: [INTRODUCTION \(/niosh/npg/pgintrod.html\)](#) See ICSC CARD: [1118 \(/niosh/ipcsneng/neng1118.html\)](#)

Page last reviewed: April 4, 2011
 Page last updated: February 13, 2015
 Content source: [National Institute for Occupational Safety and Health \(NIOSH\)](#) Education and Information Division

Centers for Disease Control and Prevention 1600 Clifton Road Atlanta, GA
 30329-4027, USA
 800-CDC-INFO (800-232-4636) TTY: (888) 232-6348 - [Contact CDC-INFO](#)



ATTACHMENT B: Job Hazard Analysis

PROJECT HAZARD ANALYSIS		
Job Step	Potential Hazards	Risk Control Measures
Sampling of groundwater monitoring wells at the Site. – All steps.	Slip, trips, falls and muscle strains.	Do not run on Site. Do not carry objects that may obscure your vision, or are too heavy for one person to carry safely. Use proper lifting techniques. Always use the buddy system. Use mechanical lifting equipment to lift heavy loads.
	Heat stress/extreme temperature working conditions.	Minimize direct sun exposure by wearing sun hats, long-sleeved shirts, full-length pants, and applying UV barrier sunscreen. Minimize exposure to heat stress by drinking adequate fluids and performing work in the shade if possible. When the anticipated temperatures exceed 100° F, a portable shade canopy will be used and work hours will be shifted to early morning to avoid the heat of the day.
	Working at night or early morning (before sunrise).	In cases where work hours are shifted to night and early morning hours to avoid the extreme heat, workers will utilize headlamps and ensure the work area is properly lit. When working near the roadway the field vehicle will have emergency flasher lights on to provide added visual notification for vehicular traffic.

PROJECT HAZARD ANALYSIS		
Job Step	Potential Hazards	Risk Control Measures
	Insect bites/stings (includes Africanized bees)	<p>Insect repellent may be used below knee level on pants to prevent biting insects, care should be taken to not get spray on sampling gear or near personnel's hands and arms.</p> <p>If a bee hive is encountered, do not disturb or aggravate the hive. If the hive is located within close proximity of a sampling location, the location will be noted and no sample collected. Personnel will not attempt to remove or work close /around the hive.</p>
Sampling of wells within or near the roadway.	Cars and vehicular traffic.	<p>Work area will be coned off and all site workers will wear high visibility clothes/vest. If work in roadway is required a permit may be required. All permit conditions will be followed (acceptable hours/days, barricades and warning distances, flagger if required).</p>
Driving to, from, or on Site between sample wells.	Striking pedestrians, structures or other vehicles, runaway vehicles.	<p>Wear seatbelts at all times while vehicles are in motion. Use licensed drivers. Look at map before driving. Obey all driving regulations. Use emergency brake when parked. When backing up or negotiating difficult areas use a spotter.</p>

PROJECT HAZARD ANALYSIS		
Job Step	Potential Hazards	Risk Control Measures
SVE Operations and Maintenance – All Steps	Rotating machinery and belts.	Always leave belt guards and safety guards in place. If maintenance is required on moving parts, belts, or electrical components, strict adherence to Lock Out-Tag Out procedures is required. Avoid wearing loose clothing around moving machinery.
	Electrical Shock.	Prior to replacing any electrical component, ensure positive electrical disconnect and Lock Out-Tag Out procedures are in place. Power. Test any leads with meter (Multi-meter) prior to handling exposed electrical wires.
	High temperature piping and equipment.	Proper use of shielding/clothes, including gloves where required
	Chemical exposure during vapor stream monitoring.	Take care to have all sampling tubing and containers attached to sampling ports prior to opening. Only open sampling ports for sampling, do not leave open when not attached to sampling train.
	Vessels under pressure or vacuum.	Do not open vessels or access points while system is under pressure or vacuum. Examples include carbon vessel access ports, opening flange fittings in vapor stream, and the moisture separator vessel.
	Accumulated vapors in vaults	When opening vapor extraction well vaults, let the vault space vent/exchange air prior to working within the space.

PROJECT HAZARD ANALYSIS		
Job Step	Potential Hazards	Risk Control Measures
Well drilling and installation/work in City streets w' traffic	Cars and vehicular traffic, work around drill rig (rotating equipment, overhead equipment)	Work area with radius the height of the drill rig will be coned off (if feasible) and all site workers will wear high visibility clothes/vest. If work in roadway is required a permit may be required. All permit conditions will be followed (acceptable hours/days, barricades and warning distances, flagger if required). Follow all details in the SOPs for utility clearance, work in streets (plus any added permit requirements) and well drilling.
Substrate Injection for biological/ERD treatment/ work in City streets w' traffic	Cars and vehicular traffic, work with substrate liquids, pumps, power source	All site workers will wear high visibility clothes/vest. If work in roadway is required a permit may be required. All permit conditions will be followed (acceptable hours/days, barricades and warning distances, flagger if required). Follow all details in the SOPs for work in streets (plus any added permit requirements) and ERD substrate injection.

Attachment C: Tailgate Pre-field Briefing and Safety Plan Review

_____ Date; Workers Present: _____

Purpose of Field Work and Site Details

1. ____ Review purpose and scope of work
2. ____ Review anticipated chemicals present and concentrations expected

Safety Plan Review

1. ____ Review chemical hazards and exposure limiting controls:

No eating, drinking, smoking, and chewing while in the work area

2. ____ Identify physical hazards
 - a) Visibility, hearing, and dexterity (may be impaired by PPE)
 - b) Monitoring well considerations: open monument, sharp edges, and biological hazards.
 - c) Housekeeping/debris management
3. ____ Be aware of heat stress when the temperature exceeds 70 degrees Fahrenheit
 - a) Expected high temperature of the day, planned work hours, shade
 - b) Plenty of cold drinks and ice in cooler
 - c) Planned *minimum* hydration rate (____ Liters/hour)
4. ____ Identify possible fire hazards
5. ____ Review PPE: Level D to be worn at all times
 - a) Hardhat (when applicable)
 - b) Work gloves (or Nitrile gloves when sampling) will be worn in the work area
 - c) Safety glasses or face-shield (if applicable)
 - d) Steel-toe boots
 - e) Long pants and long sleeves (*long sleeves optional*)
 - f) Wide brimmed hat (when in the sun) and Sunscreen
 - g) Hearing protection (when/if applicable)
 - h) High visibility safety vest (or equivalent)
6. ____ Review Site control plan (exclusion zones, decontamination, waste management, and hazard communication)
7. ____ Review emergency procedures and direction to nearest hospital

ATTACHMENT C
PERMITS

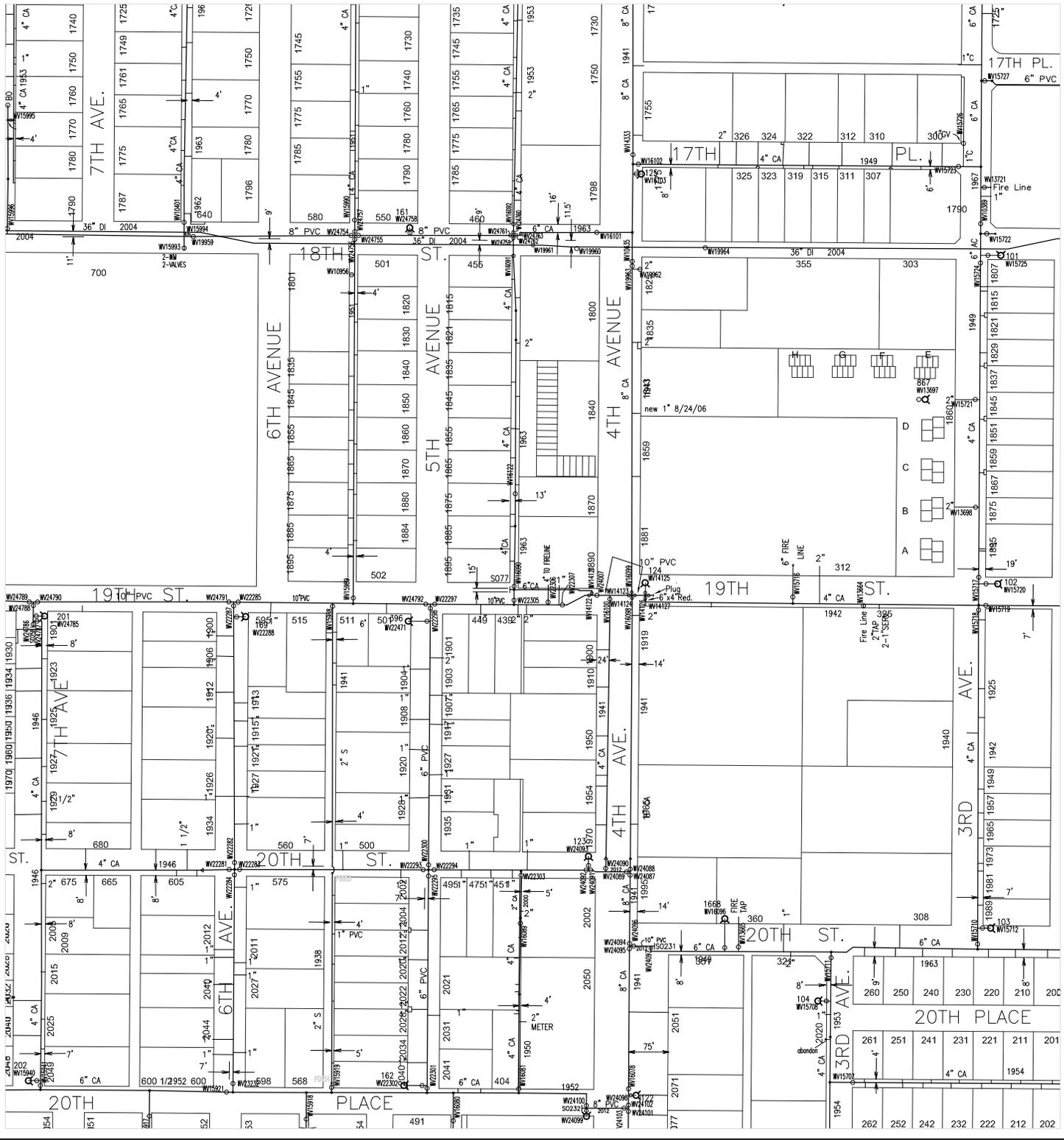
ATTACHMENT D

Local Utility Maps, Details, Utility Clearance

WATER DISTRIBUTION SYSTEM

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230000

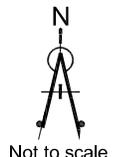


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Prepared by:
City of Yuma
 City Engineering Department



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Map Number

1523

Revision Date:

July 2014

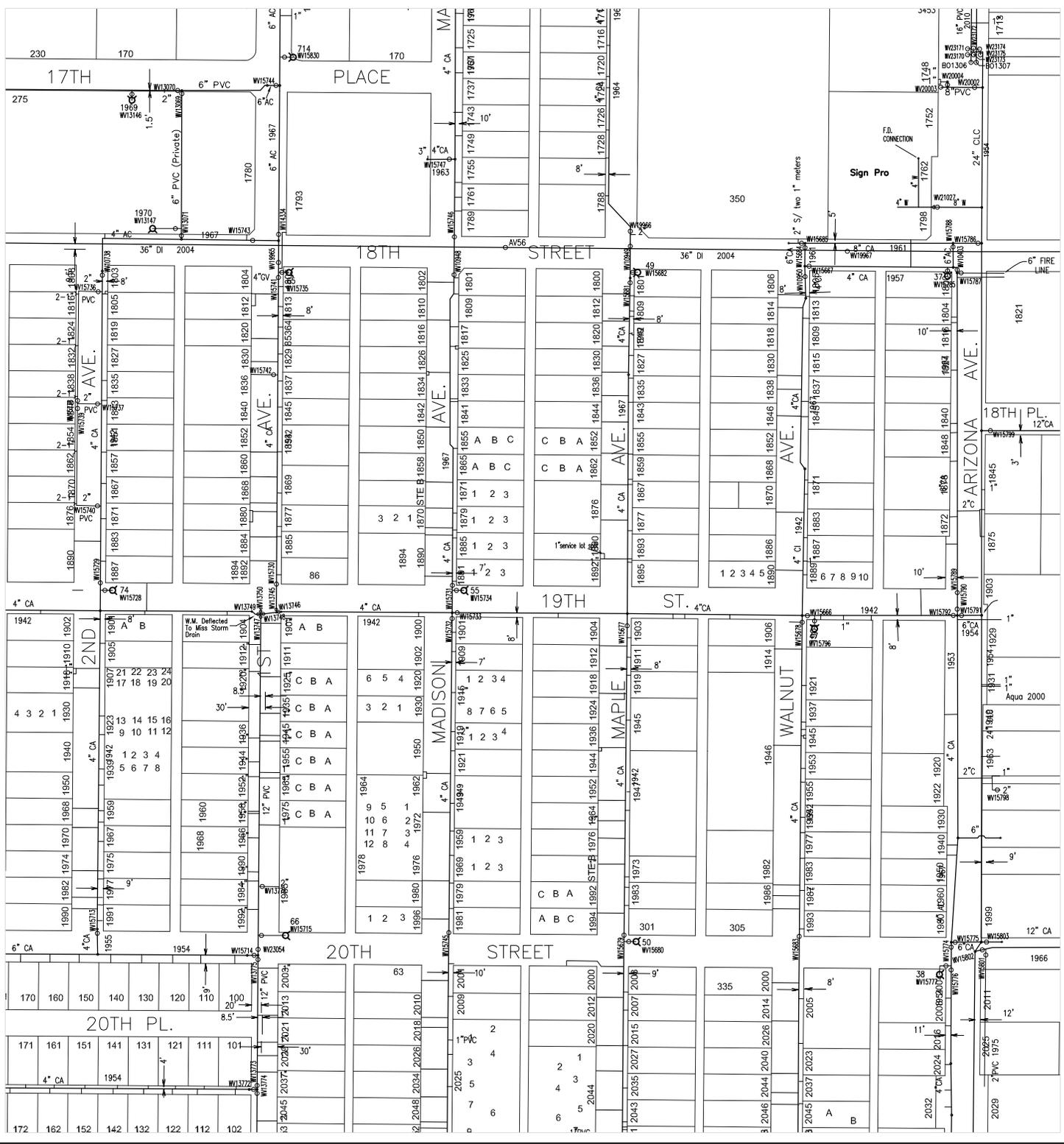
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WATER DISTRIBUTION SYSTEM

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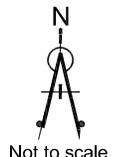
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City of Yuma
 City Engineering Department



Map Number

1524

Revision Date:

July 2014

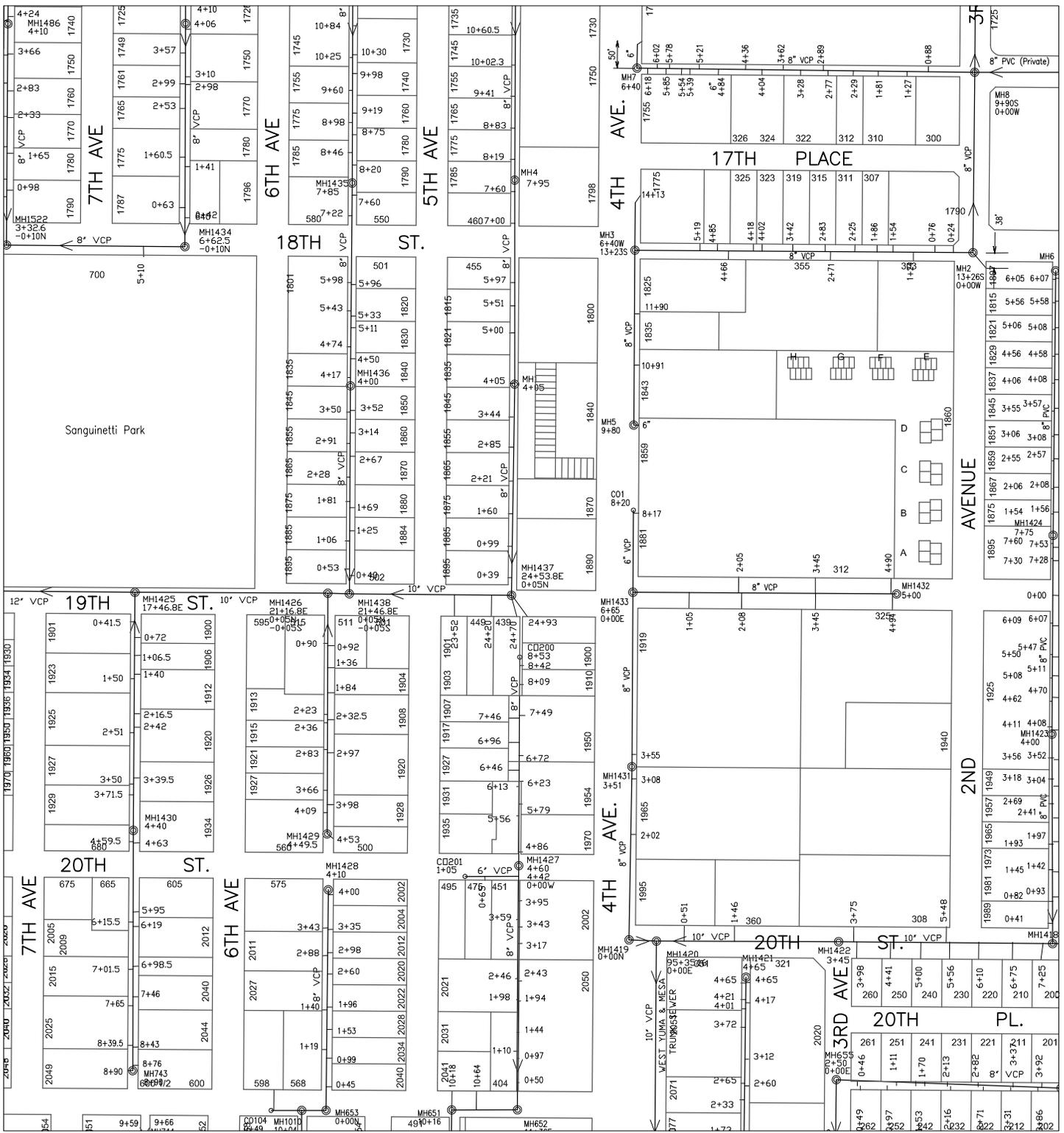
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Sanitary Sewer Collection System

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City Engineering Department



Scale: None

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Map Number

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Revision Date:

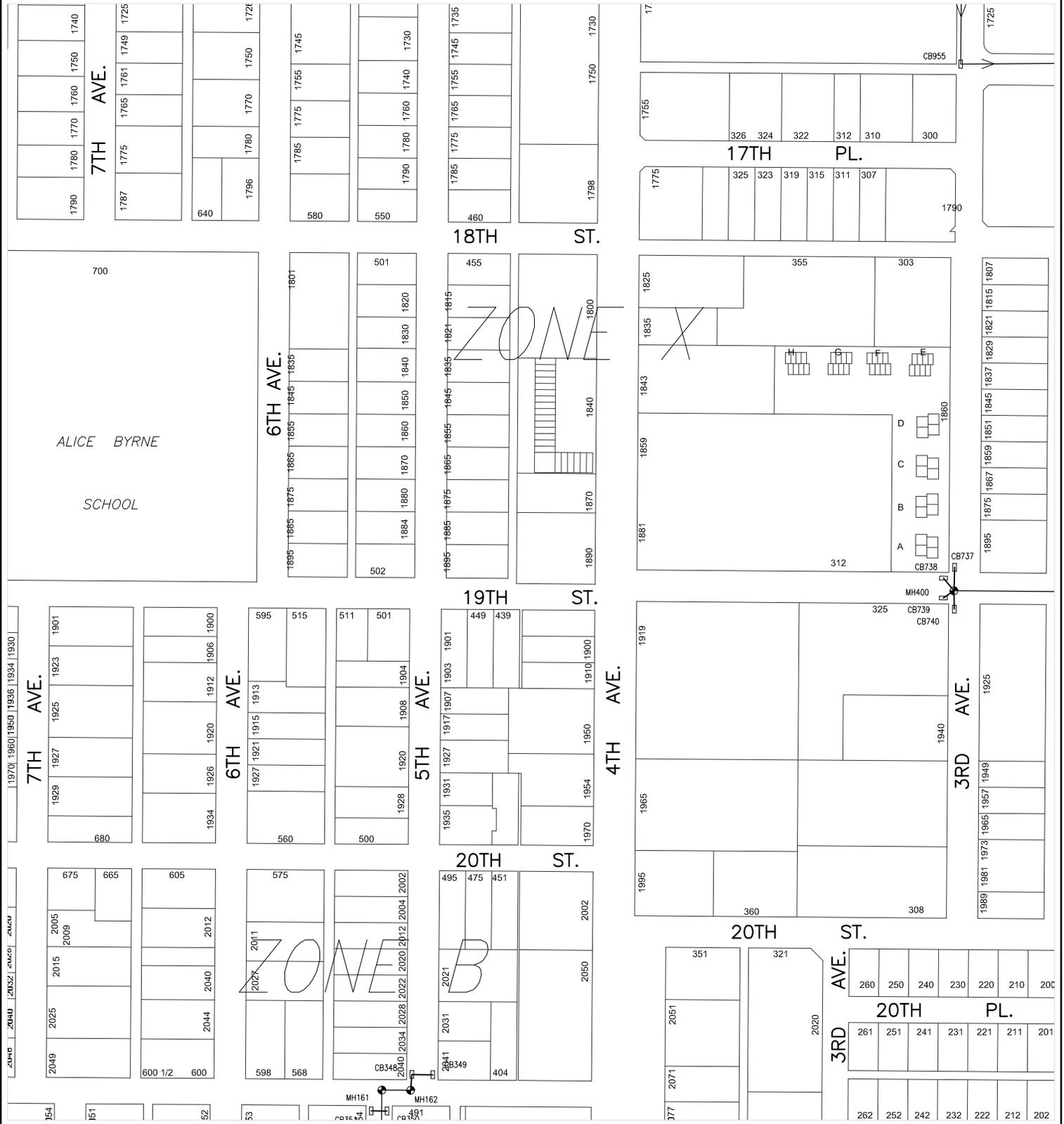
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STORM WATER COLLECTION SYSTEM

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616000



Prepared by:
City of Yuma
Department of Public Works
Engineering Division



Not to scale

1422	1423	1424
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Map Number

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Revision Date:

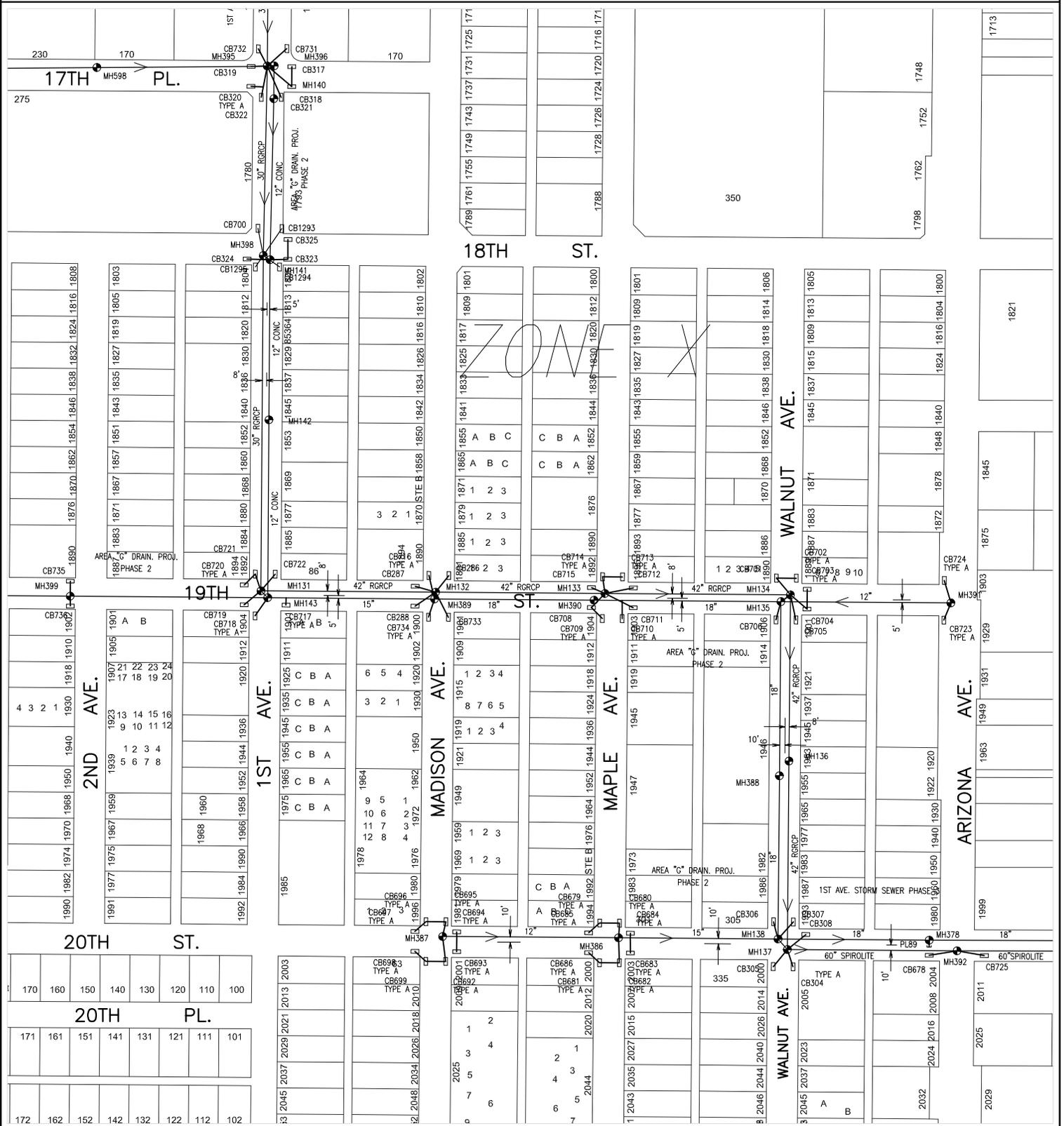
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STORM WATER COLLECTION SYSTEM

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Prepared by:
City of Yuma
Department of Public Works
Engineering Division



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Map Number

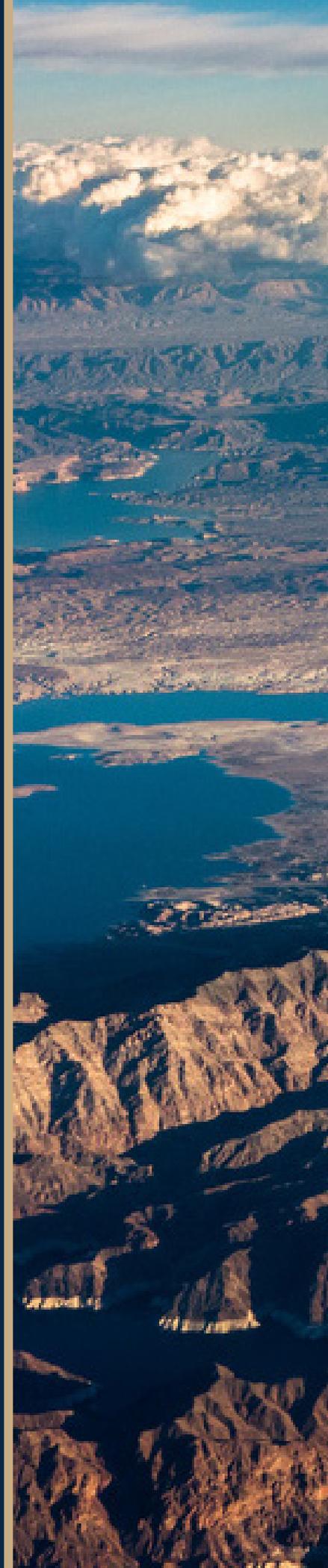
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